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May 2003

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The reasons for this overwhelming acceptance of Meade LX90 and LX200GPS telescopes are clear: advanced technology at the very leading edge of telescope design and including the patented Autostar control system; legendary diffraction-limited optical systems with optionally-available ultra-high transmission coatings; and uncanny 1-arcminute High-Precision Pointing in the GO TO mode that positions objects on even the smallest CCD chips.

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Packing & shipping charges in the 48 states: 8" LX90 – $95; 8" LX200GPS – $105; 10" – $145; 12" – $215; 14" – $265; 7" – $125. Prices shown are suggested U.S. national mail-order retail prices. Certain Meade telescopes and Autostar control systems are manufactured under U.S. Patent Nos. 6,304,376 and 6,392,799; other patents pending in the U.S.A. and worldwide. Special LX90 and LX200GPS prices are valid for purchases from authorized Meade dealers in the U.S.A. **between September 15, 2002 - April 30, 2003.**

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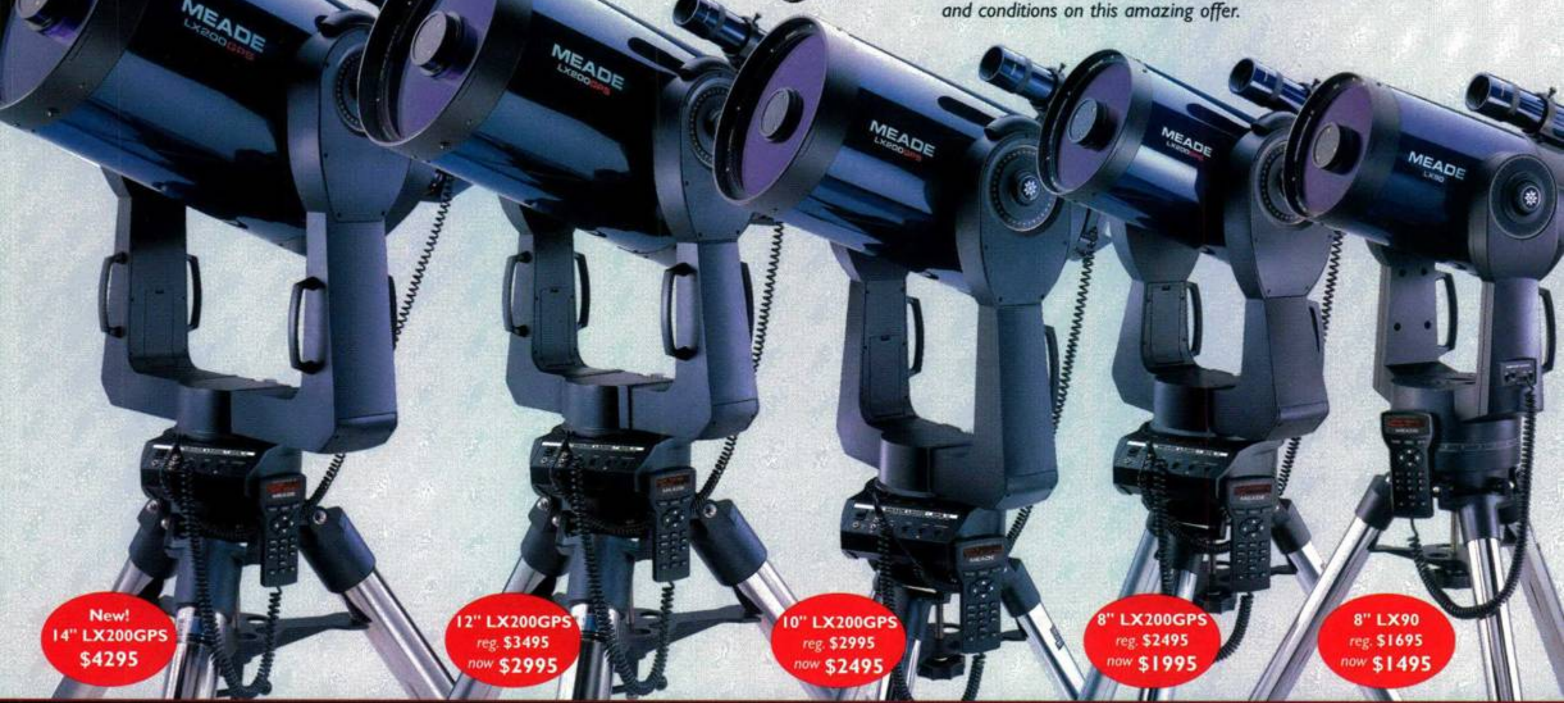
Through April 30, 2003, you can buy a full set of Meade premium-grade Series 4000 Super Plössl eyepieces, packed in a Meade #771 aluminum carrying case, for only **$99** with the purchase of a Meade LX90 or LX200GPS telescope. *See the full-page Meade ad in this issue for complete terms and conditions on this amazing offer.*



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A Comparison of GPS Schmidt-Cassegrain Telescopes

	Meade 8", 10", 12", 14" LX200GPS	Competing 8" and 11" GPS
Primary Mirror Lock	Yes; standard equipment. Cancels residual mirror shift during visual, photographic, or CCD imaging applications	No
Zero Image-Shift Microfocuser	Yes; standard equipment. Operates from Autostar II handbox and permits 4-speed microfocusing, while maintaining precise image centration during CCD imaging	No; must be purchased separately from an alternate supplier at a cost of approx. $200 to $300
Download of Software Revisions	Yes; the latest software version, as well as custom and updated guided tours, comet and asteroid positions, may be downloaded in minutes, and at no charge, from the Meade website	No; software and data stored in the hand controller are not updatable without returning the hand controller to the factory; motor control software upgrade or debugging requires complete replacement of the electronic circuit board in the fork arm assembly
Software Download, Automatic GO TO, and Automatic Tracking of Earth Satellites	Yes; current earth satellite orbital data (including International Space Station, Space Shuttle, etc.) may be downloaded; telescope then automatically acquires and tracks satellite at correct tracking rate	No
True-Level Tripod Sensor	Yes; automatically compensates to a precision of 10-arcminutes for user error in leveling tripod during GPS alignment	No; absence of true-level sensor requires user to precisely level the tripod **manually**. Mis-leveling of the tripod by user results in alignment star errors of up to 5° or more during GPS alignment
Maximum Slew Speed	8° per second	3° per second
Time Required to Perform a 120° Slew	15 seconds	40 seconds
Drive Speeds, each axis	185 speeds, from 0.01x sidereal to 8° per second	9 speeds, from 0.5x sidereal to 3° per second
Tracking Rates	sidereal, lunar, or custom-selected from 2000 rates	sidereal, lunar, or solar
Celestial Object Database	147,541 objects	40,000 objects
High-Precision Pointing Mode	Yes; permits GO TO pointing precision within 1-arcminute	No
Flash Memory	3.5-Meg	1.0-Meg
Permanent Periodic Error Correction	Yes, both axes	One axis only; second axis unprogrammable
Encoder Resolution	0.14 arcsecs	0.26 arcsecs
Internal Battery Compartments for cordless powering	Yes; user-supplied C-cell batteries located inside the fork arms negate any need for external power cords. (If desired, telescopes may alternately be powered by external cord.)	No
Multi-Coated Correcting Plate	Included with optional UHTC; increases light transmission by about 2% and reduces internal tube reflections	Not included and not available as an option
Enhanced Optical Coatings	Optional UHTC group results in light transmission **greater than 85%** at **all** wavelengths between 450nm - 700nm and transmission of **90% to 94%** at wavelengths between 540nm - 690nm, a range which includes the important Hα line at 656nm	Competing 11" coatings have a **peak** transmission of 85% at 510nm; **light transmission at all other visual wavelengths, including the Hα line, is below 85%**
Hand-Matched Optics	Yes; since their inception in 1980 all Meade Schmidt-Cassegrain optics have been individually hand-matched. Individual match-figuring is performed on the large correcting plate, resulting in a smooth optical figure	Yes; individual matching is performed on the small secondary mirror
Primary Mirrors	Oversize diameters (8.25" on 8" LX200GPS; 10.38" on 10" LX200GPS; 12.38" on 12" LX200GPS) result in increased edge-of-field illumination	Mirror diameters (8" telescope includes 8.1" mirror; 11" includes 11.1" mirror) result in lower edge-of-field illumination
GPS Antenna	Omnidirectional, located squarely on top of fork arm; GPS signals are receivable through a larger sky-area	Omnidirectional, but location at approx. 45° angle inside fork arm results in approx. 45° sky-area being inaccessible to GPS signals
Field Tripods	8" and 10" tripods include 2"-dia. chromed steel legs; 12" and 14" tripods include 3"-dia. chromed steel legs; all tripods include a **cast aluminum** leg-lock spreader bar	8" and 11" tripods include 2"-dia. painted steel legs and a **plastic** leg-lock spreader bar
Polar Axis Bearings	1 x 4" dia. ball bearing and 1 x 2.25" dia. ball bearing mounted coaxially to the polar axis. Both bearings contribute to radial and axial stiffness	1 x 1.88" dia. roller bearing mounted coaxial to the polar axis and 3 x 0.88" dia. ball bearings rolling on an unshielded aluminum track. Only the 1.88" bearing contributes to radial stiffness
Swing-through of optical tube in fork arms	Yes; telescope can observe 100% of sky area	Yes; telescope can observe 100% of sky area
FCC (U.S.A.) and CE (Europe) certified for low electromagnetic interference	Each telescope carries a label confirming FCC and CE certifications	Telescopes do not carry any labels confirming domestic or foreign certifications

Comparisons are based on current Meade LX200GPS models and on competitive telescopes and user manuals received in 11/2002.

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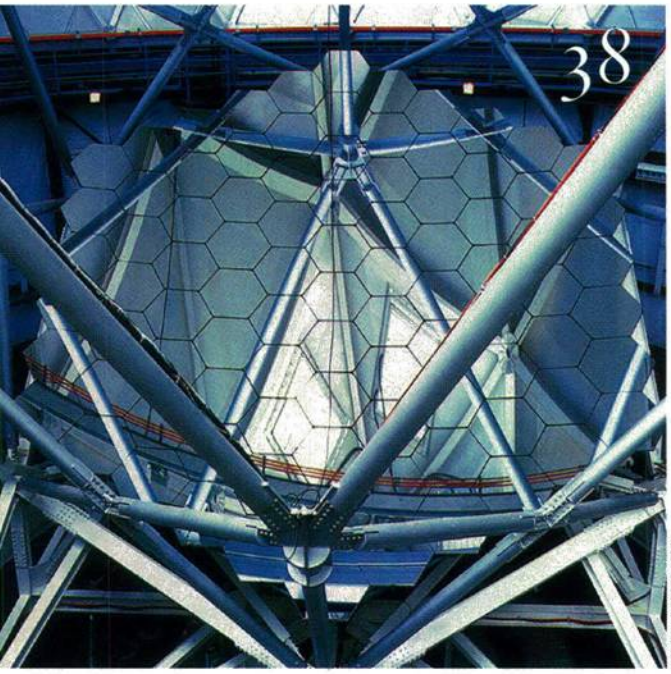

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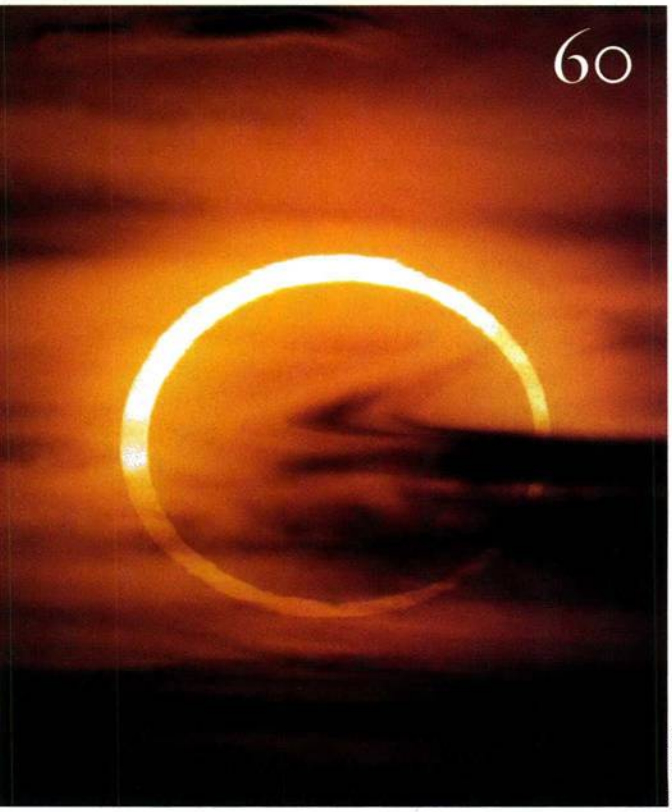

PHIL LOHMANN

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Astronomy
Giant new scopes transform the cosmos

ON THE COVER
A thermal-infrared picture of Jupiter and its moon Io (a composite image) made with the Very Large Telescope in Chile reveals details of the jovian magnetosphere. A ring of aurora is visible at Jupiter's poles, and bright and dark volcanic features are visible on Io. The images were made with the ISAAC infrared imager on the 8.2-meter ANTU VLT in 2001. ESO

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BIG GLASS: Earthbound vs. space telescopes, active vs. adaptive optics, and other telescope topics

BIG SCIENCE: Through the eyes of graduate students

GALACTIC CIRCUS: A collection of weird galaxies

MINORITIES IN ASTRONOMY: The whole truth

GOING LOONY: Crater timings for May's lunar eclipse

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BY DAVID J. EICHER

The quest for big glass

Contributing editor William Schomaker, a resident of the historic district of Atlanta, Georgia, gets around. Having earned his bachelor's degree in physics at the University of Georgia and master's in astronomy from the University of Wisconsin, he spent a couple of years at *Astronomy* before retreating to the warm South. An energetic student of current astrophysical research, his latest writing project focuses on the new large ground-based telescopes that are springing up and giving the Hubble Space Telescope a run for its money. Schomaker's article "Big Glass" (page 38) highlights the new generation of powerhouse optical and infrared telescopes.

CONTRIBUTING EDITOR William Schomaker follows big telescopes. HEATHER SCHOMAKER

Schomaker's research on the story produced some 50 pages of interview notes from talking to astronomers who have used the new glass giants. "Talking to Geoff Marcy during his observing run at Keck was a highlight of producing this story," he says. "I awoke at 4 A.M. one morning and caught him as he and Paul Butler were beginning to hunt Saturn-like planets that night." Marcy welcomed Schomaker into the process by telephone and "even paused our conversation as they acquired the next star on the list and adjusted the spectrometer." Marcy described how he now normally observes from Keck headquarters at Waimea rather than trekking to the summit of Mauna Kea, and how he plays tennis during the day and eats at posh restaurants.

Schomaker heard comments from several observatory directors that seemed like they were talking about their now-grown children. "Matt Mountain of the Gemini Observatory has spent years watching an idea once sketched on a cocktail napkin blossom into a great engine of multinational science," he says. Although the new generation of ground-based scopes rivals the performance of Hubble, the technological steps forward have really laid the groundwork for an even more impressive game now unfolding — the development of 30- to 50-meter-class telescopes.

"No longer will it be like the biologist and the lab coat," asserts Schomaker. "Remote observing will separate the telescope from the astronomer, and the astronomer's best friend may become a well-hammered keyboard in a cozy office." It's not as dramatic an image as Edwin Hubble, pipe in pocket, climbing into Palomar's observing cage, but it's progress . . .

Yours truly,

DAVID J. EICHER
Editor

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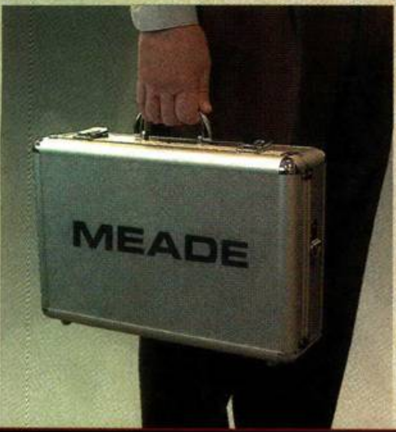

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LX90, LX200GPS models:	8" LX90; 7", 8", 10", 12", 14", 16" LX200GPS

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Other terms and conditions: Payment may be made by personal check (payable to Meade Instruments) or credit card (VISA or MasterCard). **California residents must add $7.67 sales tax, for a total payment of $106.67.** Requests for this special offer must be postmarked not later than May 31, 2003. This special offer is valid only for new Meade telescopes ordered and received within the U.S.A. (Outside the U.S.A. contact your Meade international distributor.) There is no limit to the quantity of telescopes each person may order: each qualifying telescope is eligible to receive the special eyepiece package. Prices shown are suggested U.S. mail-order retail prices. **The SP26mm eyepiece (shown in photos above) is packed with each qualifying telescope as standard equipment.

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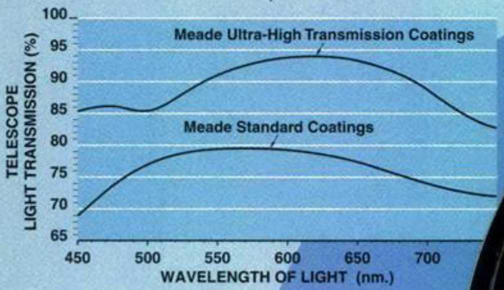

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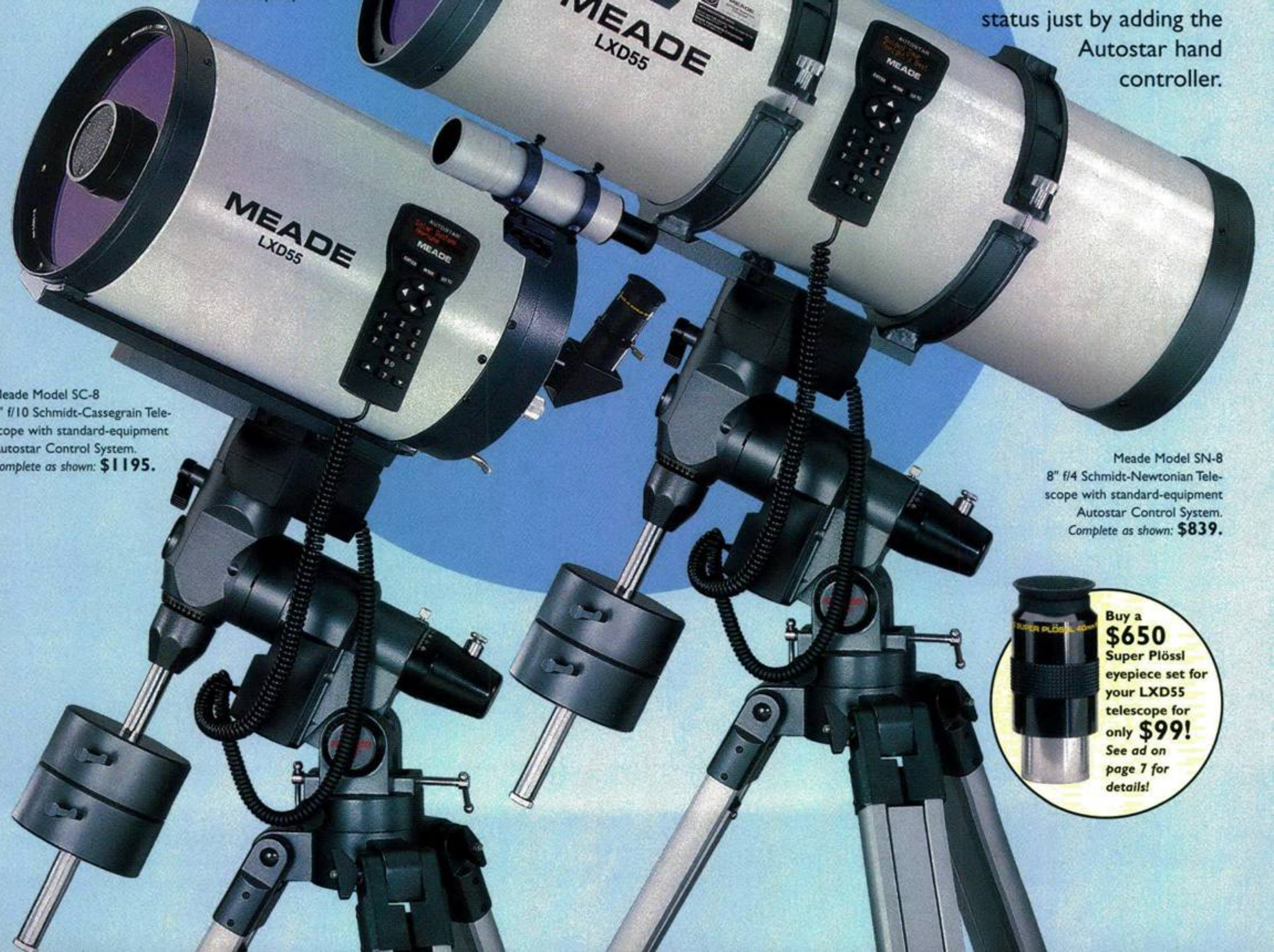

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SPECIFICATIONS: Models SN-6, SN-8, and SN-10 Schmidt-Newtonian Telescopes — Each complete telescope includes 6" f/5, 8" f/4, or 10" f/4 Schmidt-Newtonian optical tube assembly with MgF_2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally); white-enameled metal optical tube with machined-aluminum mirror cell; quick-release cradle ring assembly with locks; 6 x 30mm achromatic viewfinder; metal rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces; Series 4000 Super Plössl 26mm eyepiece. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12v DC auto cigarette lighter plug or from 115v AC home outlet); operating instructions.

6" Model SN-6 Schmidt-Newtonian	**$695**
8" Model SN-8 Schmidt-Newtonian	**839**
10" Model SN-10 Schmidt-Newtonian	**995**

Ultra-High Transmission Coatings (UHTC) group: 6" Model SN-6 – $85; 8" Model SN-8 – $125; 10" Model SN-10 – $150.

Packing & shipping charges in the 48 states: 6" – $75; 8" – $85; 10" – $95.

MEADE
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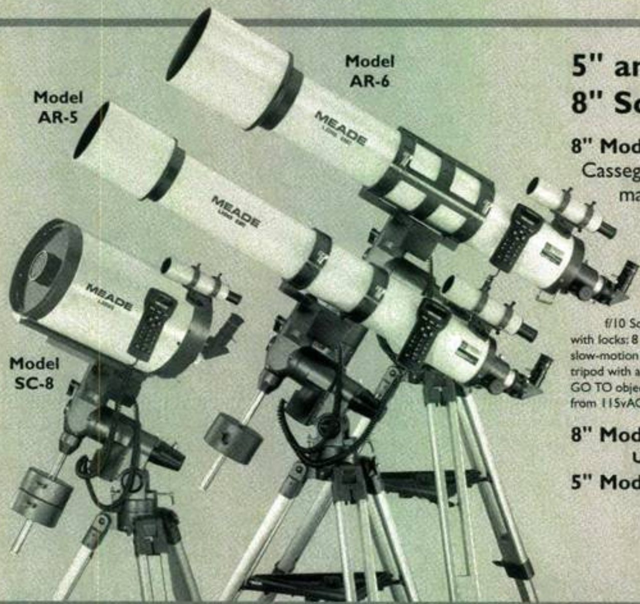
Model SN-6
6" Schmidt-Newtonian with Autostar

Model SN-8
8" Schmidt-Newtonian with Autostar

Model SN-10
10" Schmidt-Newtonian with Autostar



Model AR-6

Model AR-5

Model SC-8

5" and 6" LXD55-Series Achromatic Refractors and 8" Schmidt-Cassegrain with Autostar

8" Model SC-8: Includes the f/10 optical system of the Meade 8" LX200GPS for razor-sharp Schmidt-Cassegrain photo-visual imaging of the Moon, planets, and deep-space. All the telescope required by many amateurs for a lifetime of serious observing. **5" Model AR-5, 6" Model AR-6:** Excellent optical performance from the classical 2-element achromat design, with images rich in resolution and contrast and a minimum of chromatic aberration. Models SC-8, AR-5, and AR-6 allow for the full range of Autostar functions described above.

SPECIFICATIONS: Models SC-8 Schmidt-Cassegrain and AR-5 and AR-6 Achromatic Refractors — Each complete telescope includes 8" f/10 Schmidt-Cassegrain with MgF_2/standard coatings or 5" f/9 or 6" f/8 achromatic refractor with EMC super multi-coatings; quick-attach cradle ring assembly with locks; 8 x 50mm viewfinder; Series 4000 Super Plössl 26mm eyepiece; diagonal prism. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); operating instructions.

8" Model SC-8 Schmidt-Cassegrain . . $1195
UHTC group for Model SC-8 — $175
5" Model AR-5 Achromatic Refractor . . 695

6" Model AR-6 Achromatic Refractor . . 895

Packing & shipping charges in the 48 states: 8" – $85; 5" – $85; 6" – $95.

6" and 8" LXD55-Series Schmidt-Newtonians and 5" Achromatic Refractor with Electronic Controller

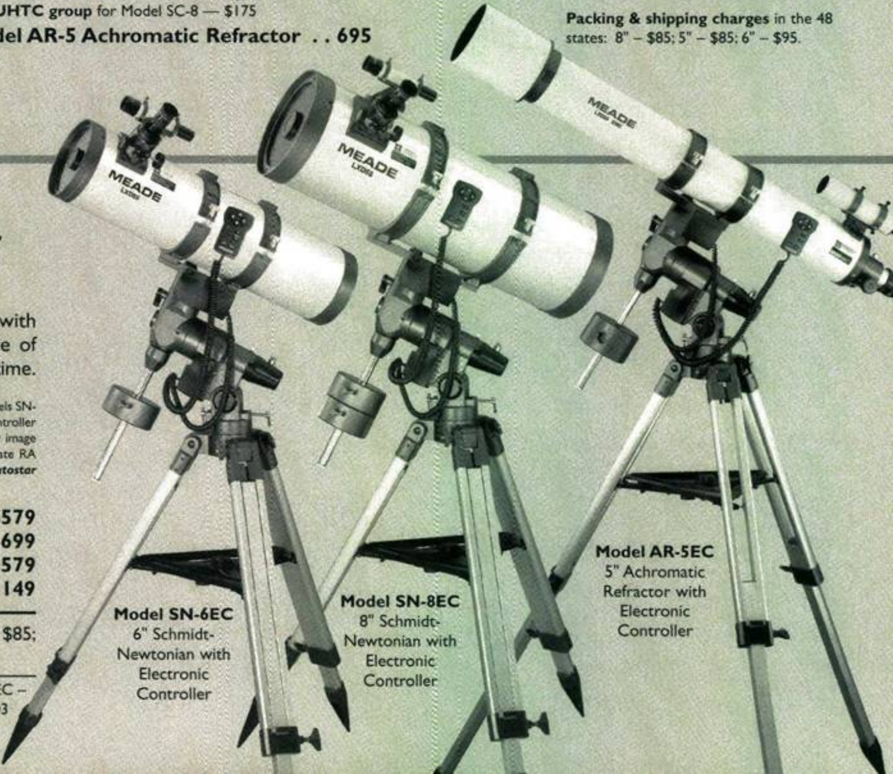
All the performance and features of the Autostar models above, but with 4-speed (2x, 8x, 32x, 4.5°/sec.) dual-axis Electronic Controller in place of Autostar. Upgrade to the Autostar Controller, available separately, at any time.

SPECIFICATIONS: Models SN-6EC, SN-8EC, and AR-5EC — Identical in every detail to the respective Models SN-6, SN-8, and AR-5, above, but with Electronic Controller (EC) in place of Autostar Hand Controller. Electronic Controller includes four dual-axis slewing speeds: 2x for photoguiding; 8x for image centering in the main telescope; 32x for image centering in the viewfinder; 4.5°/second for rapid-slew of the telescope across the sky; plus automatic sidereal-rate RA tracking. ***#497 Autostar Controller may be added at any time in the future and permits the full range of Autostar functions, including automatic GO TO, as described for Autostar-equipped telescopes, above.***

6" Model SN-6EC Schmidt-Newtonian	**$579**
8" Model SN-8EC Schmidt-Newtonian	**699**
5" Model AR-5EC Achromatic Refractor	**579**
#497 Autostar Controller, for any EC-model above	**149**

Ultra-High Transmission Coatings (UHTC) group: 6" Model SN-6EC – $85; 8" Model SN-8EC – $125.

Packing & shipping charges in the 48 states: 6" SN-6EC – $75; 8" SN-8EC – $85; 5" AR-5EC – $85. All prices shown in this ad are suggested U.S. national mail-order retail prices. © 2003



Model SN-6EC
6" Schmidt-Newtonian with Electronic Controller

Model SN-8EC
8" Schmidt-Newtonian with Electronic Controller

Model AR-5EC
5" Achromatic Refractor with Electronic Controller

MEADE®

RESEARCH-GRADE ACCESSORIES

Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or studying tenuous nebulosity in deep-space, Meade SP's deliver unmatched contrast and image sharpness. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each: **$79.95** (4.54)
32mm (52°); **40mm** (44°)	each: **99.95** (5.26)
56mm (52°; 2")	**199.95** (7.02)

Series 4000™
2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (5.26)

Series 4000™ Super Wide Angle
67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 4000™
Ultra Wide Angle
84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels.

$16.95 (2.73)

Series 3000™ Plössls
50° field; multi-coated

Clearance Sale!

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm (*far right in photo*), an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$29.95** (3.86); **40mm $39.95** (3.86)

Series 4000™
f/6.3 Focal Reducer/
Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (5.26)

#911B
#911N
#908B
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (4.54)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (4.54)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (5.26)

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade 60-layer interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia.	**99.95** (4.54)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**149.95** (5.26)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (4.54)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces.

$49.95 (5.26)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (4.54)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (4.54)

New! 2" Diagonal Mirrors with UHTC

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes UHTC-coated (95%+ reflectivity) precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

#929 or **#930,** each: **$119.95** (6.85)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.86)

Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

#1206 Electric Focuser: Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. (Not for LX200GPS models.)

$149.95 (7.48)

#1205 Electric Focuser: For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

$169.95 (7.88)

#777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

$79.95 (6.85)

Vibration Isolation Pads

Designed by Meade engineers, these isolation pads reduce typical telescope-tripod vibration damping times to less than one second. A tremendous aid for both visual and photographic astronomy. Place one pad under each tripod leg. #895 Vibration Isolation Pads, per set of three:

$49.95 (6.85)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator.

$79.95 (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**; 1.25": **$29.95** (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (3.86)

CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with any brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope." — Jack Newton

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XTE, ST-7, or AP1, or smaller; or visual observing with 1.25" eyepieces.
$149.95 (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XTE, or ST-4 through ST-10; or AP2, AP7; or for visual applications with 1.25" or 2" eyepieces.
249.95 (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.)
15.00 (3.86)

#644

#647

#1209 Zero Image-Shift Microfocuser

Identical to the Microfocuser supplied with Meade LX200GPS telescopes, but provided with a separate hand-box for use with all other Meade SCT models (e.g., LX10, LX50, LX90, LX200) or for Schmidt-Cassegrains of other brands. Threads directly to the telescope's rear cell. Permits extremely precise focusing of the image during visual or photographic applications; during CCD applications maintains precise image centration on even the smallest CCD chips. Operates at four speeds, from extremely slow to fast; accepts both 2" and 1.25" eyepiece barrels. Requires 8 x AAA (user-supplied) batteries.

$249.95 (9.85)

Epoch 2000® Sky Software

The most powerful astronomical software ever made available can now be yours for only $99!

Epoch 2000sk *(upper display at left)*: Use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** Dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely! Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

Epoch 2000ip Image Processing Software: Enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet.

EPOCH 2000sk Sky Software: 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM for Windows 95, 98, 2000, NT, and XP **$99**

LX200 Interface Cable: for Meade LX200/LX200GPS operation by Epoch 2000sk. **25**

EPOCH 2000ip Image Processing Software: On CD-ROM for Windows 95, 98, 2000, NT, and XP **99**

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated: 41mm clear aperture.

$149.95 (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models; ST-4 through ST-8; AP1, AP2; and others. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above)*. Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25".

$129.95 (4.54)

#825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing.

$49.95 (4.26)

#64 T-Adapter for ETX®

Threads to photo port of all ETX-90, ETX-105, and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera.

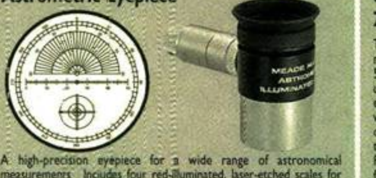
$34.95 (3.86)

#932 45° Erecting Prism for ETX®

For terrestrial observing with any ETX-90, ETX-105, or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics.

$49.95 (3.86)

MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25".

$119.95 (4.26)

Series 4000™ 8mm – 24mm Zoom Eyepiece

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25".

$219.95 (6.38)

ETX® Hard Carrying Cases

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, optional eyepieces, erecting prism, table tripod, hand controller, etc. Includes steel latches & key.

#774 Case for ETX-90 models:
99.95 (8.58)

#776 Case for ETX-105EC:
99.95 (8.58)

#775 for ETX-125EC:
149.95 (13.38)

Dew Shields for ETX®

Threads into the front-lens cell and effectively inhibits the formation of dew on the lens surface.

#670 for ETX-60/70	19.95
#673 for ETX-90	24.95
#675 for ETX-105	27.95
#678 for ETX-125	29.95

Electronic Eyepiece

#902: Permits transmission of live, real-time black-and-white images of the Moon and planets from your telescope to TV monitor, VCR, or camcorder. Uses a CMOS detector of 320 x 240 pixels. Includes barrels for both .965" and 1.25" focusers. "Simple to use and inexpensive, the Meade Electronic Eyepiece is a great first step for anyone looking to enter the universe of video astronomy…Not only will the Meade imager show remarkable views in real time, but when used with a VCR, a frame grabber, and a computer, it is capable of producing fine still images, too." –*Sky & Telescope*, 2/03. Includes 6 ft. cable; requires 9v. (user-supplied) battery.

$69.95 (7.02)

ETX® Deluxe Field Tripod

#1184: Constructed of strong, lightweight steel; designed specifically for ETX-90, ETX-105, and ETX-125 Astro Telescopes. Tripod height adjusts from 25" to 43", for seated or standing observations. Graduated scale for elevation angle from 20° to 90° permits precise polar alignment of the telescope for astronomical applications. Tripod tilts and locks at 98° for terrestrial applications or for altazimuth use with Autostar. Telescope attaches to tripod in seconds with 2 thumbscrews. **Includes custom-fitted carry bag (shown) with pocket for accessories.**

$199.95 (10.00)

#771 Aluminum Carrying Case

High-quality, lightweight aluminum, suitable for storage of eyepieces, camera adapters, filters, etc. Fully foam-lined. 15" x 10" x 5".

$49.95 (5.78)

Electric Focusers for ETX®

Meade-engineered for smooth, rapid focusing with ETX-90, -105, or -125. Four-speed operation from coarse to microfine. Standard-equipment hand controller accepts one 9v. (user-supplied) battery and focuses all ETX telescopes. Or focus through the telescope's Electronic Controller (EC) or through Autostar.

#1244 Electric Focuser for all ETX-90 and ETX-105 models:
$119.95 (6.85)

#1247 Electric Focuser for ETX-125 models:
$119.95 (6.85)

Pictor 216XT CCD Autoguider/Imager

The most advanced Autoguider/Imager in its price class. For many, all the CCD imager required for a wide range of lunar, planetary, or deep-space applications. Includes the same "point-and-shoot" simplicity of larger Pictor models. Produces smooth, natural 16-bit images of all celestial subjects. Also a precision autoguider during astrophotgraphy.

$695. (12.00)

HOW TO ORDER

Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes. Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price. **The following national mail-order dealers carry Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

OCEANSIDE PHOTO & TELESCOPE, Oceanside, CA.
Orders & Information: 800-483-6287.

ANACORTES TELESCOPE, Anacortes, WA.
Orders & Information: 800-850-2001.

RIVERS CAMERA, Dover, NH.
Orders & Information: 800-245-7963.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 847-367-4600.

WOODLAND HILLS CAMERA & TELESCOPE, Woodland Hills, CA. Orders: 888-427-8766; Info.: 818-347-2270.

EFSTONSCIENCE, Toronto, Ontario, Canada
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario, Canada
Orders & Information: 416-783-4140.

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THE LARGEST-SELLING TELESCOPES IN THE WORLD

MEADE

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NATIONAL

RITZ CAMERA CENTERS

Over 1000 Locations Nationwide

Call **800-52-FOCUS** *for nearest location*

www.ritzcamera.com

ARIZONA

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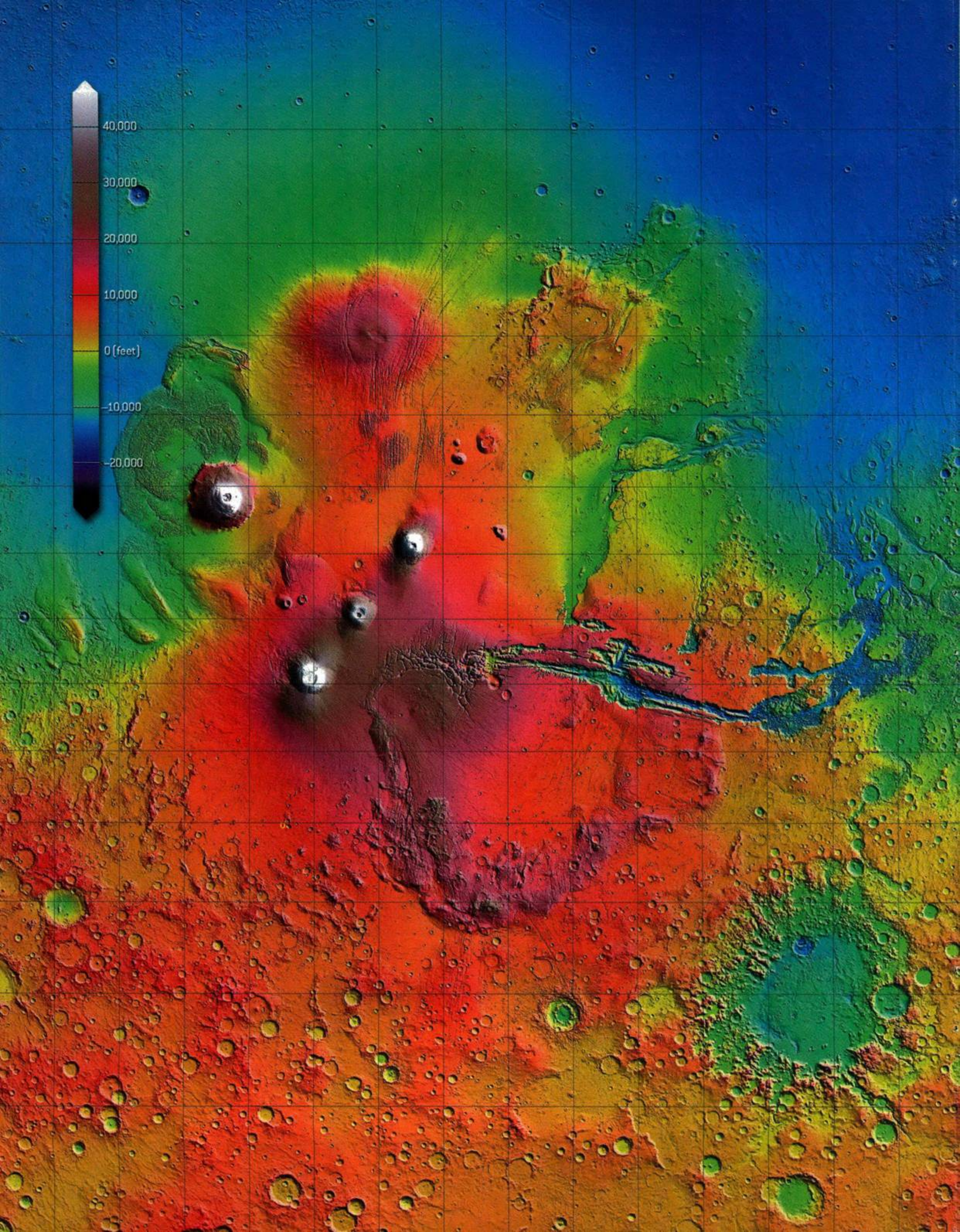
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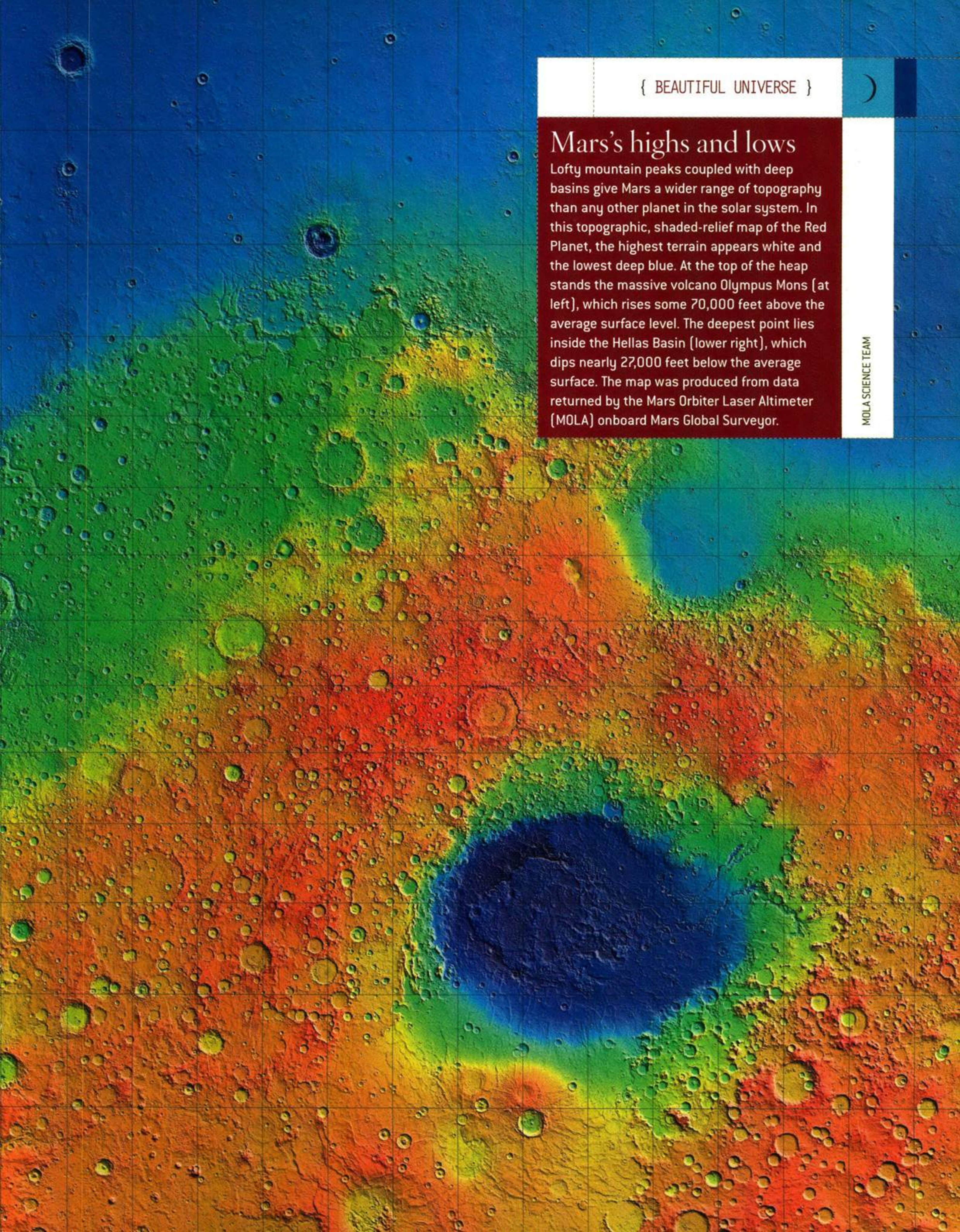

Mars's highs and lows

Lofty mountain peaks coupled with deep basins give Mars a wider range of topography than any other planet in the solar system. In this topographic, shaded-relief map of the Red Planet, the highest terrain appears white and the lowest deep blue. At the top of the heap stands the massive volcano Olympus Mons (at left), which rises some 70,000 feet above the average surface level. The deepest point lies inside the Hellas Basin (lower right), which dips nearly 27,000 feet below the average surface. The map was produced from data returned by the Mars Orbiter Laser Altimeter (MOLA) onboard Mars Global Surveyor.

MOLA SCIENCE TEAM

Southern skies

After returning from my second trip of observing in Australia, I read "The Sky's Top 10" (February) with interest. But I was disappointed at the lack of deep southern objects in the article. Too many northern observers are unfamiliar with the wonders in the southern sky, such as the Eta Carinae Nebula (NGC 3372), the Tarantula Nebula (NGC 2070), Omega Centauri (NGC 5139), 47 Tucanae (NGC 104), the Orion Nebula (M42), and Centaurus A (NGC 5128). The Orion Nebula was the only object included in this list. For observers interested in more information on southern sky objects, check out the website of the Astronomical Society of New South Wales, www.asnsw.com.
— **ROBERT J. DOUGLAS,** SAN FRANCISCO STATE UNIVERSITY, CALIFORNIA

CENTAURUS A (NGC 5128), located in the constellation Centaurus, is one of the many gems of the night sky visible from southern skies. JAMES R. FOSTER

Helpful hints for the LX90

I read John Shibley's "Test-driving Meade's LX90" (February) with interest, since I've long thought the LX90 to be a standout in the now-crowded go-to SCT field. The article was well written and detailed, and most of the time I found myself nodding in agreement. But one item caught my attention.

Shibley comments that the Allen-type collimation screws used on this telescope can be a hassle to adjust in the dark. Very true! However, he then goes on to advise the LX90 owner to replace these with some "oversized hand knobs available at hardware stores." This is a good idea, but removing and replacing these screws can bring disaster (if the secondary mirror drops onto the primary mirror) or dissatisfaction (if the screws are of the wrong length to allow proper adjustment of the secondary) to uninformed users. In addition, the SCT user does not need to suffer with inconvenient Allen or Phillips adjustment screws. At least two vendors that I know of — Bob's Knobs (www.bobsknobs.com) and Scopestuff (www.scopestuff.com) — sell "Nobs" to replace the original collimation screws used in SCTs. These come with detailed instructions that will allow the user to safely replace the original screws. They will also be properly sized for a particular telescope model. — **ROD MOLLISE,** AUTHOR OF *CHOOSING AND USING A SCHMIDT CASSEGRAIN TELESCOPE.*

Seeing stars

Fred Ringwald's superb article, "Seeing Double," (January) identifies the location of the quadruple star Nu Scorpii as in "the sting at the tail of the Scorpion." While the coordinates given are correct, "Nu" is actually in the claws next to the bright double Beta Scorpii. It was apparently confused with the star "Upsilon," which is located in the stingers next to Lambda Scorpii.

Several excellent showpiece pairs were not mentioned in the article. Among them are the colorful Iota Cancri (the "Spring Albireo"), 145 Canis Majoris (the "Winter Albireo"), 24 Comae Berenices (another beautiful Albireo look-alike), Cor Caroli (Alpha Canum Venaticorum), and Beta Scorpii itself. For anyone desiring to explore more of these jewels of the heavens, my book, *Celestial Harvest: 300-Plus Showpieces of the Heavens for Telescope Viewing & Contemplation* (Dover Publications), features more than 150 showpiece double and multiple stars. — **JAMES MULLANEY,** EXTON, PENNSYLVANIA

Correction

On page 97 of the February issue, the star at the top of the page is incorrectly labeled Capella. The star is actually Beta Aurigae. — ***ASTRONOMY* EDITORS**

We welcome your comments. Send letters to Astronomy Letters, P.O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.

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BY WILLIAM SCHOMAKER

Geoff Marcy

The reality of planets circling distant stars is so fresh to most of us; we still don't know what to make of it. But University of California-Berkeley astronomer Geoff Marcy has been on the front lines of this transformation of science fiction to reality all along. He was obsessed with the possibility of planets beyond the solar system when David Lee Roth was still with Van Halen, long before claiming his first exoplanet in 1995. Now with more than 100 known exoplanets out there, Marcy has become a hero of modern science and, no doubt, is destined to become a hero of history.

Yet despite having been crowned today's uncontested exoplanet ambassador, having graced the stage of "The Late Show with David Letterman" and the cover of *Time*, Marcy will be the first to argue that his has been anything but a solo journey. At least twelve colleagues tirelessly search the sky with him.

Be prepared. What he has to say about planets and life is sure to surprise you.

Several of your colleagues thought you were crazy to abandon promising magnetic field research to hunt for exoplanets. What drove you to ignore their advice and go for it anyway?

After getting my Ph.D. I felt that my research on magnetic fields was unsuccessful and that my abilities as a scientist were inadequate to continue. As a last-ditch effort, I searched for a research topic that was meaningful to me personally, even if beyond the technical reach of existing equipment. While showering in my Pasadena apartment one morning in 1983, I hit on the question: Is our solar system unique, and are there other Earths? I figured that extraordinarily precise Doppler measurements could reveal planets, and I had nothing to lose by trying.

GEOFF MARCY dedicates his life to searching for other earthlike planets, to discover just how unique we really are. PEG SKORPINSKI

How have things changed for you since your first exoplanet discovery?

Before finding planets, Paul Butler and I were allocated three or four nights per year on telescopes to do the planet search. Now our team receives about 100 nights per year, including time on the wonderful Lick, Keck, Anglo-Australian, and Magellan telescopes. These telescopes are blazing the trail toward finding planets with rocky surfaces capable of cradling lakes, streams, and oceans.

What's been the general response to your paradigm-shifting and potentially faith-shattering work?

I haven't had much response from the religious community, except two inquisitive calls from the Vatican Observatory. Still, a shift in our human connection to the galaxy seems to have occurred overnight. There's a realization now that future human exploration should focus on other worlds and their environments.

The SETI researchers scour extrasolar planets for radio and optical signals from intelligent civilizations. Their work, previously considered fringe science, is now considered the next logical step in the human search for our place in the galaxy. Clarke, Asimov, and Sagan were right: Our human destiny lies in maturing both introspectively and outwardly as we find our place in the universe.

Given the available data, what's your prognosis for the existence of earthlike exoplanets?

We know that gas-giant planets exist around 10 percent of all stars. Smaller, terrestrial planets are almost certainly even more common. Among the 200 billion stars in our Milky Way Galaxy, there must be 100 billion Earth-sized planets. Many of them are lukewarm, heated either by their host star or by geothermal and tidal processes. The ingredients of life are common in the galaxy, namely atomic elements, organic molecules, and heat energy. On the surfaces of other Earths there must be quiet ponds and lakes containing that remarkable transparent liquid stuff that is essential for life.

Is civilization prepared to encounter life beyond Earth?

We humans seem barely prepared to coexist with the life we have right here. No, we are not prepared to encounter extraterrestrial life — just ask our terrestrial friends, the innumerable species who struggle against extinction.

I hope we can soon begin to view our tiny Earth as the marvelous cosmic oasis that it is. ■

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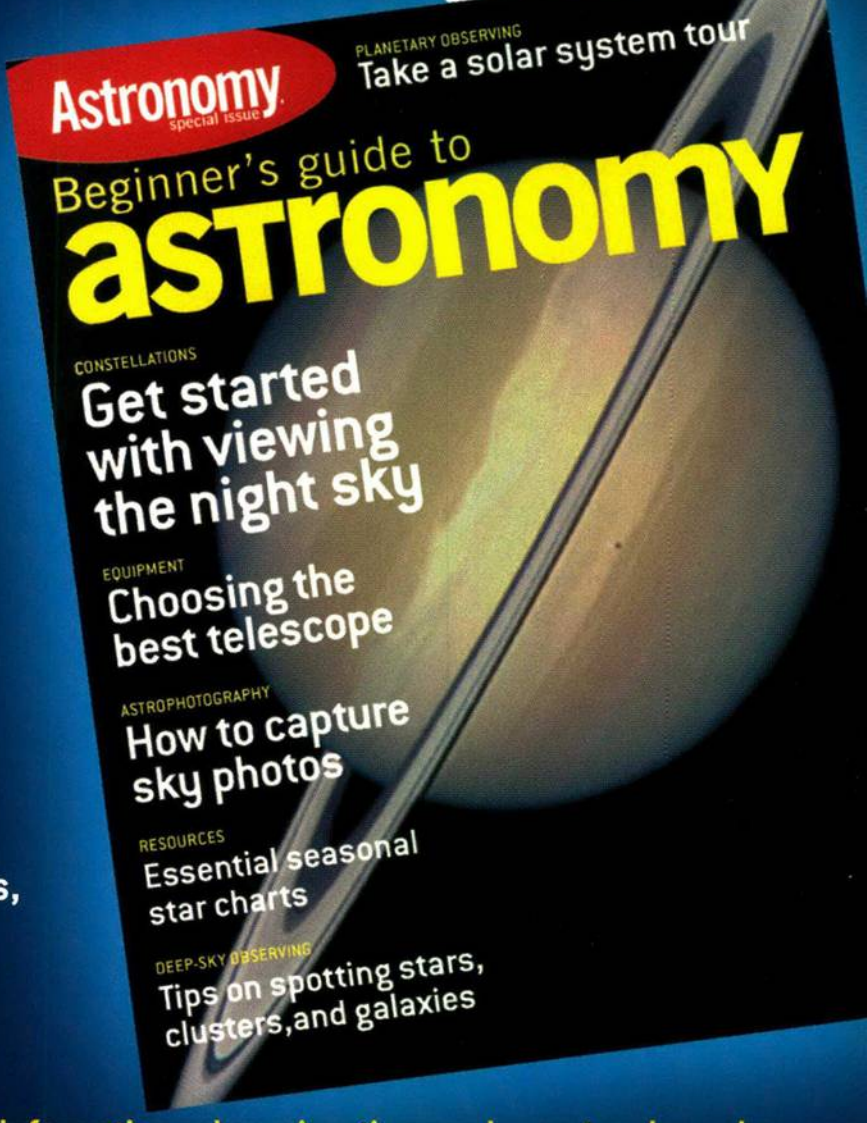
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BY BOB BERMAN

Lunar eclipses

Very odd indeed, that most of the U.S. will see *two* total eclipses this year. Such a double whammy happens only a few times a century. Rarer still is that they're both convenient-hour events; nobody has to set an alarm. But then what? Unlike solar eclipses, the lunar variety offers little opportunity for scientific gain. May 15 will make headlines, but is it media hype with little substance, a sort of comic-book astronomy unworthy of backyard cognoscenti like us?

Actually, no. Especially when you focus on lesser-known aspects. Like that voodoo word "penumbra," which all by itself makes television anchors mess up their eclipse announcements. Consulting an almanac beforehand, they think the action starts with the beginning of the penumbral eclipse. Tip: Pretend "penumbral" spells out the word "zero." If you were transported to the ideal place on the Moon (the eastern edge) where the penumbral eclipse begins — and didn't mind getting your eyes fried — you could attempt to see a speck of Earth block a tiny segment of the dazzling Sun. Meaning, you'd see nothing. And looking up from here, nothing's happening either. It's a common mystifier. Each year I write the astronomy section of a major almanac, but in the current edition an overzealous editor "corrected" my data and inserted the penumbral starting time. Result: People will look up and wait. And wait some more. So just skip ahead to 10:03 P.M. EDT for the debut of the partial stage.

The Moon is the only known body whose speed matches its diameter: It alone moves through space its own width each hour. No surprise, then, that it takes that long to fully enter Earth's shadow. During this time, the Moon is said to go through a "series of phases," but it's really much stranger than that. Earth's shadow tapers like a chopstick to roughly half its original width at the Moon's distance — still about twice the Moon's size. So a lunar eclipse is a geometric wonderland involving curves with two different radii. They do not match. (Earth's shadow has a curve that compares with the lunar terminator only when the Moon is two days from its half phase.) When do these interacting curves produce their weirdest dreamlike effects? Answer: When the shadow falls near the lunar limb, around the beginning and end of the partial stages, roughly 10:10 and 11:05 P.M. EDT and again around 9:15 P.M. PDT. If you want to impress impatient beginners, have 'em look up during the TMS: Times of Maximum Strangeness.

Lunar eclipses appear best through binoculars or just the unaided eye. The Full Moon is never a good telescope target, and hosting the blurry-edged shadow of Earth doesn't help much. It's not terrible, like macaroni salad, but Earth's shadow edge is fuzzy, and fuzzy is not a good thing through an eyepiece.

Consider: A 4-inch scope has a resolution of about one arcsecond. By coincidence, one arcsecond is approximately one mile on the Moon. Now, each mile or arcsecond from the eclipse line shows you lunar terrain dimmed by just another 0.0005 of the Sun's full brightness. The fade-out is disappointingly gradual. Very low power comes to the rescue by sharpening the line, making it more striking. And as long as you're lugging gadgetry around, don't forget your camera or camcorder — lunar eclipses are easy to shoot and yield impressive results.

Notice how Earth's shadow looks black during the early partial eclipse but then turns a different color when the eclipse is almost total. What gives? My guess is it's actually red from the beginning since our planet throws a red shadow into space. (Earth's sunrises and sunsets combine into a brilliant crimson ring around the black cameo of Earth that's cast onto the eclipsed Moon.) But the red's brightness level is so low that when the partial eclipse starts, the Full Moon's brilliance makes our retinas compensate by under-exposing the shadow area, blackening it.

Spend part of the night looking elsewhere. Before and after the eclipse you'll see the countryside bathed in brilliance by the Full Moon, bringing out the greens of spring foliage. The sky itself, pale and bright, will be empty of all but a few stars. Totality transforms everything: Now the non-urban landscape becomes inky and colorless. The sky floods magnificently with thousands of faint stars. Libra, which looks like a "Scale" only to substance abusers, may pop out behind the Moon. Deep-space observing opens up as galaxies and globulars regain their glory. From eastern states (where it's risen), the Milky Way materializes. Totality offers a quick Moon-versus-Moonless comparison, an effective reminder of why many amateur astronomers loathe the Full Moon.

The event's climax may be its single unpredictable aspect: color. Totality can be black, brown, gray, red, copper, orange, or yellow-white, depending on the light reaching the Moon. It varies with the atmospheric dust, clouds, moisture, and pollution around Earth's limb. The lunar eclipse is thus the only celestial event where we look at another world but get an environmental report card about ourselves. And if we don't like what we see, hey, we get another chance on November 8. ◼

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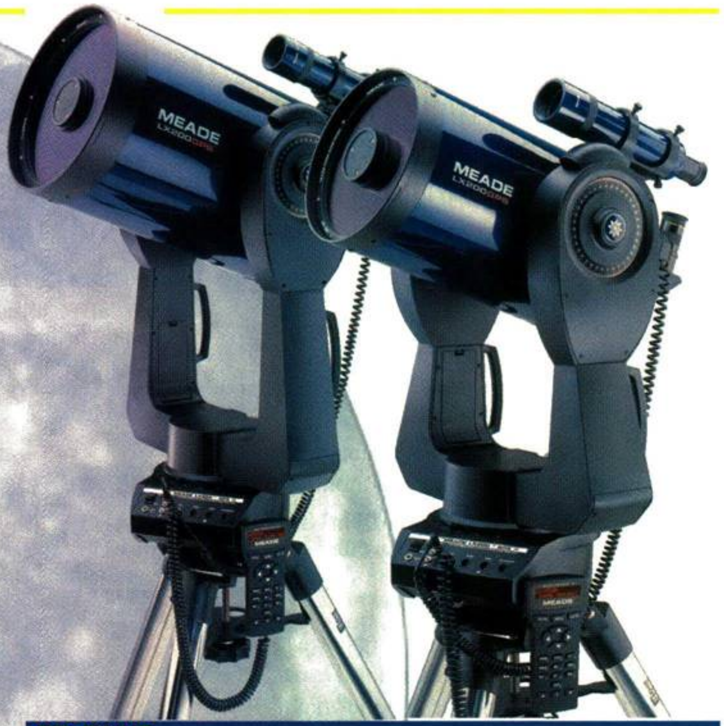

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BY GLENN CHAPLE

Phase transitions

Quick question: What phase will the Moon be in tonight? If you know the answer, chances are you're a pretty dedicated observer. If you haven't a clue, you belong to the majority of people who, thanks to the conveniences of the modern world, don't spend enough time outside to become familiar with the lunar cycle. Or perhaps you are a serious skygazer who lives in New England, where it's cloudy so often we can't remember what the Moon looks like at all.

Let's stamp out L.P.I. (Lunar Phase Ignorance) by spending the month following our nearest neighbor as it goes through a complete cycle around Earth.

May 1: New Moon

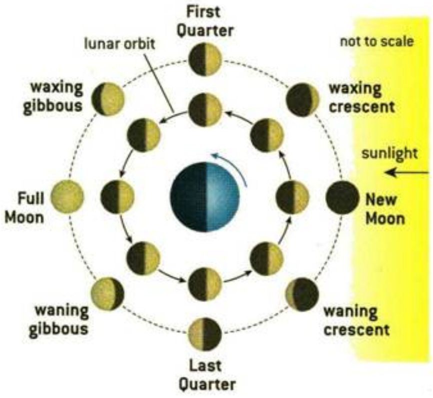
The lunar cycle begins with New Moon, which occurs at 8:15 A.M. EDT. Don't bother looking for the Moon tonight — it's between us and the Sun, hidden by the solar glare.

May 2 to 8: Waxing crescent Moon

After new phase, the Moon drifts to the left (east) of the Sun. It appears as a crescent in the western sky after sunset (it starts out so thin you probably won't see a thing until the 3rd or 4th). With each passing night, the Moon will move about 12° farther east of the Sun, becoming larger ("waxing" means growing) and easier to see. A bonus — the bright "star" you see near the crescent Moon on the evenings of May 4 and 5 is Saturn; Jupiter will shine near the Moon on the 8th.

May 9: First Quarter Moon

The "half Moon," as poets call it, shines brightly to our south at sunset. Why do astronomers refer to this phase as a "quarter"? I like to tell my students that the Moon has traveled one-quarter of the way around Earth since New Moon. Also, we see only a quarter of the Moon's total surface (half of the half of the Moon that faces us).



THE MOON'S ORBIT constantly changes the angle between Earth, Moon, and Sun, causing lunar phases (outer circle). ROEN KELLY

May 10 to 14: Waxing gibbous Moon

The Moon gets fuller and keeps moving farther from the setting Sun. (Gibbous means "bounded by convex curves" and occurs when the side of the Moon we see is more than half illuminated.)

May 15: Full Moon

Ah, the Full Moon — a time when lovers go for moonlit walks, and werewolves jump out of the darkness to devour them. The Moon has now gone halfway around Earth since the new phase and sits opposite the Sun in the sky. It's a brilliant silvery circle that rises in the east as the Sun sets in the west. Normally, this would be a poor time to skygaze (a bright Full Moon is nature's version of light pollution, blotting out all but the brightest stars). But on this night, the Full Moon will drift into Earth's shadow and become eclipsed. For tips on viewing this event, check out pages 80 and 88.

May 16 to 21: Waning gibbous Moon

Each night after the full phase, the Moon rises about an hour later. The phases now go in reverse as the Moon wends its way back toward the Sun. On the 16th, a bright waning gibbous Moon will be setting in the west as the Sun rises in the east. Each morning after, the Moon will be about 12° closer to the rising Sun. On the morning of the 21st, the Moon flirts with Mars.

May 22: Last Quarter Moon

The Moon graces the southern sky at sunrise, its left side illuminated.

May 23 to 30: Waning crescent Moon

The Moon is fading fast — an ever-shrinking crescent that draws nearer and nearer the rising Sun. You'll probably lose track of it around the 29th.

May 31: New Moon

We're back where we started, with one minor difference. This New Moon will pass directly in front of the Sun, producing an annular solar eclipse (sadly not visible from most of the United States).

Did you notice that it took 30 days to return to new phase? This isn't a coincidence — our calendar month is based on the lunar cycle, which you can recreate with a table lamp (the Sun) and a baseball (the Moon). Remove the lampshade, and hold the ball between yourself and the lamp — this is New Moon. Move the ball counterclockwise (to your left). You'll see all the phases we described here (even a lunar eclipse, as the baseball drifts into your shadow). But nothing beats the real thing, so go outside and say hello to the Moon. Clear skies!

Calculus Is the Exploration of Just Two Basic Ideas. Master Them and Open Up a New World for Yourself!

Change and Motion: Calculus Made Clear on Video

Calculus has made it possible to build bridges that span miles of river, travel to the moon, and predict patterns of population change. To understand calculus is to achieve a more profound understanding and appreciation of life... not only of the way we live, but also of the inner workings of nature and the universe.

Yet for all its computational power, calculus is the exploration of just two ideas, both of which arise from a commonsensical analysis of motion! All a calculus textbook is, Professor Michael Starbird asserts, is these two ideas—the derivative and the integral—and lots of examples, variations, and applications.

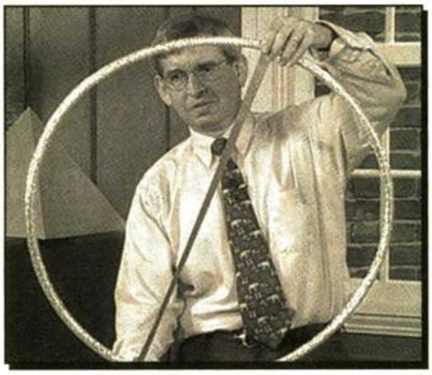
What You're Really Studying Is Change

Calculus is a unique and extraordinarily effective tool for studying change. The methods it uses to study and model motion are identical, mathematically, to the structures that model aspects of economics, traffic flow, finance, electricity, baseball, and many other topics.

A central goal of this course is to teach the concepts of calculus as meaningful ideas. Your instructor—a Distinguished Teaching Professor at The University of Texas at Austin—takes the approach that every equation is, in fact, also a sentence that can be understood in English! As a result, you will explore calculus through simple, striking ideas that give this subject its true meaning. The concepts and insights at the heart of calculus take center stage in an accessible and lively presentation.

Here's What You Need to Know to Start

Professor Starbird is a distinguished and highly popular teacher with an uncommon talent for making the wonders of mathematics clear to non-mathematicians. A central goal of Professor Starbird's lectures is to teach the concepts of calculus as *ideas* rather than *symbols.*



This course requires only a basic acquaintance with beginning high-school level algebra and geometry. Due to the extensive use of graphics, as well as objects for demonstrations, this lecture series is only available in video format. Your video course comes with complete lecture outlines and useful storage cases.

Not Convinced? Maybe This Will Help

For a limited time, you can get **Change and Motion: Calculus Made Clear** for a special price of just $54.95 on video, a savings of $145 off the regular price! This offer is being made to introduce you to The Teaching Company, the renowned educational publisher which records America's best college teachers for its Great Courses series.

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MICHAEL STARBIRD (Ph.D., University of Wisconsin, Madison, 1974) is a Professor of Mathematics and a University Distinguished Teaching Professor at The University of Texas at Austin. He is deeply interested in bringing the intrigue and fascination of mathematics to those who are not necessarily mathematically oriented. The American Mathematical Monthly acclaimed his recent book, *The Heart of Mathematics: An Invitation To Effective Thinking*, co-authored with Edward B. Burger, as possibly the best math book—textbook or not—for non-mathematicians it had ever reviewed!

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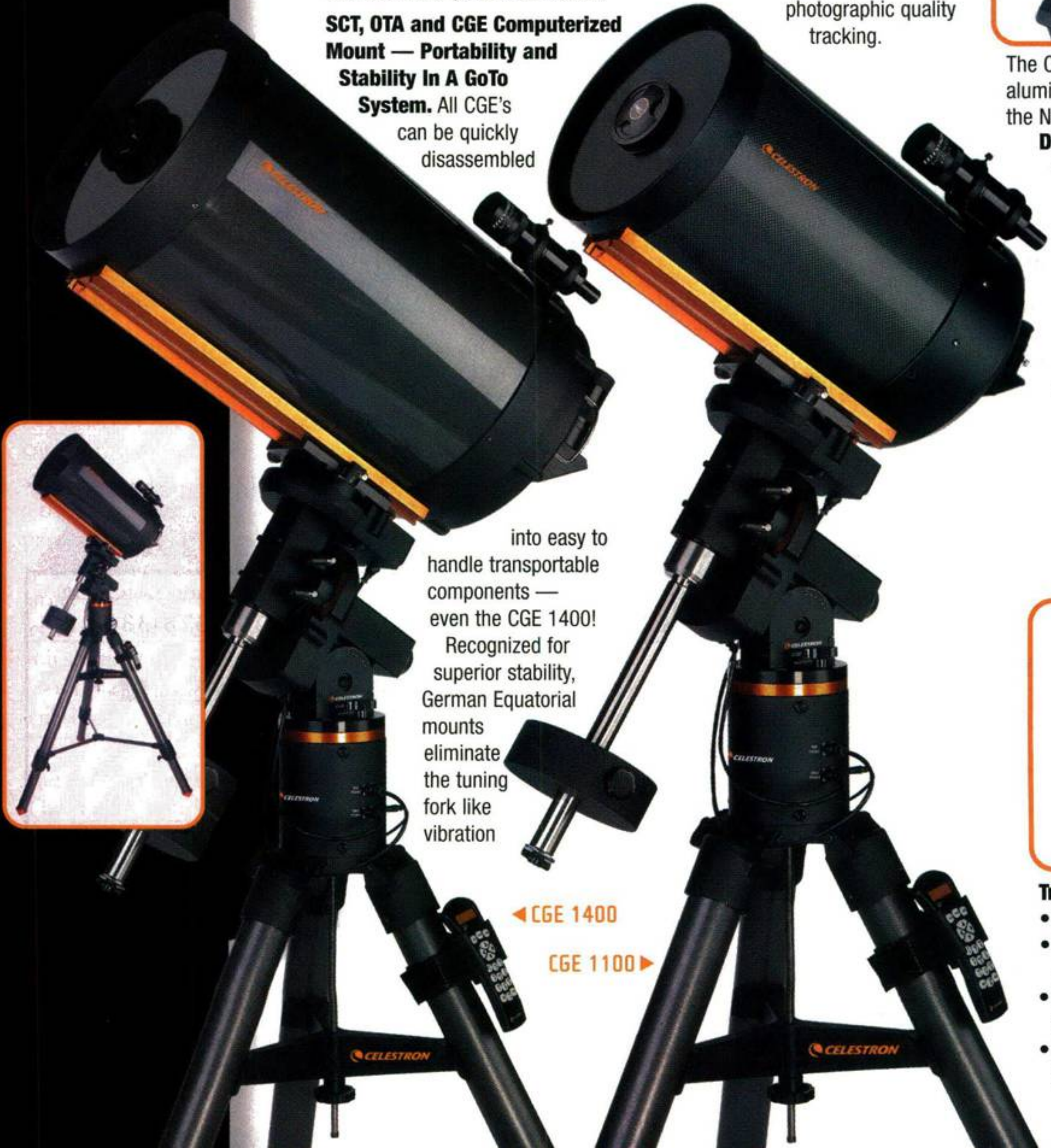
Your wait is over. You've been asking us for a complete selection of our top-of-the-line Schmidt-Cassegrains mounted on a beefy computerized German Equatorial mount. We proudly announce the CGE Series — CGE 1400-14", CGE 1100-11", CGE 925-9.25", and CGE 800-8".

SCT, OTA and CGE Computerized Mount — Portability and Stability In A GoTo System. All CGE's can be quickly disassembled into easy to handle transportable components — even the CGE 1400! Recognized for superior stability, German Equatorial mounts eliminate the tuning fork like vibration associated with fork mounted telescopes. The new CGE's are ideal for viewing objects in every part of the sky – even in the North where fork mounts have difficulty pointing.

Easy to polar align – German Equatorial mounts are the choice of the best astrophotographers.

Easy to counter balance – In both RA and Dec, for smooth photographic quality tracking.



The CGE Mount is made of CNC machined aluminum and stainless steel and features the NexStar® control system.

Drive Base Features:

- Autoguide port
- PC port
- 3 Accessory Ports
- Real time clock – maintains time even when powered down
- Strain relief power cord cable protection
- Backlit power switch

Drive System:

- U.S. manufactured Pittman 12V DC servo motors
- U.S. manufactured Berg bronze drive gear mated with stainless steel worm shafts
- 2 point RA clutch system for no slip pointing precision

Tripod Features:

- Dual Leg Support
- Center leg brace provides outward preload
- Lower leg brace provides inward preload
- Extendable powder-coated carbon steel legs

OPTICS	CGE 800	CGE 925	CGE 1100	CGE 1400
Focal length	2032mm; f/10	2350mm; f/10	2800mm; f/10	3910mm; f/11
Secondary Obstruction	2.7"	3.35"	3.75"	4.5"
Resolution (Rayleigh)	.68 arcseconds	.59 arcseconds	.50 arcseconds	.39 arcseconds
Coatings	StarBright®	StarBright®	StarBright®	StarBright®
Optical Tube	Carbon Fiber	Aluminum	Carbon Fiber	Aluminum
Fastar Compatible	Yes; f/1.95	No	Yes; f/2	Yes; f/2.1

STD. ACCESSORIES	CGE 800	CGE 925	CGE 1100	CGE 1400
Eyepiece	25mm Plössl	25mm Plössl	40mm Plössl	2" 40mm Barrel
Star Diagonal	Prism Diagonal	Prism Diagonal	Prism Diagonal	2" Mirror Diag. with $1^{1/4}$" Adapter
Finderscope	6x30	6x30	9x50	9x50
Power Supply	Car Battery Adapter	Car Battery Adapter	Car Battery Adapter	Car Battery Adapter
Counter Weights	1-11lb.	1-25lb.	1-25lb.	2-25lb.

PRICING

CGE Computerized Mount (#91524):
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CGE 800 (#11058):
$3499 + $105 Shipping & Handling
CGE 925 (#11059):
$3799 + $145 Shipping & Handling
CGE 1100 (#11061):
$4149 + $245 Shipping & Handling
CGE 1400 (#11063):
$5799 + $295 Shipping & Handling

Optional Accessories:

- 12V DC Rechargeable Power Supply (#18774)
- 2"-70° Apparent Field, Axiom Eyepieces
- Reducer Corrector; f/6.3 (#94175)
- CN16 GPS Accessory (#93963)

Specifications

Software

40,000 + Objects
400 User defined objects
Hibernate — Maintains alignment even while powered down
Polar alignment routines for Northern and Southern hemisphere
Filter limits — Displays only objects above the horizon
Permanent programmable PEC — Corrects periodic tracking errors inherent in all worm drives
Smooth ramping of slew motors to reduce wear on drive train

Electronics

Home sensors on RA and Dec axes
Real time clock
Fail safe slew limit switches in RA
12V DC Servo Motors with integrated optical encoders, 256CPR used in quadrature
Encoder resolution: .11 arcseconds

Mechanics

CNC machined aluminum and stainless steel components

RA axis

- 1" solid ground stainless steel shaft
- Two Preloaded .9835" I.D. x 2.047" O.D. tapered roller bearing
- One 4.724" O.D. x 3.543" I.D. thrust bearing
- 180 tooth, 5.625" diameter enveloping bronze gear preloaded to maintain gear mesh while clutch tension varies, manufactured to AGMA 10 quality.
- .4375" diameter precision 303 stainless steel worm, manufactured to AGMA 10 quality
- 2 point RA clutch system pre-loading a 4.65" stainless steel disk for no-slip drive and pointing precision

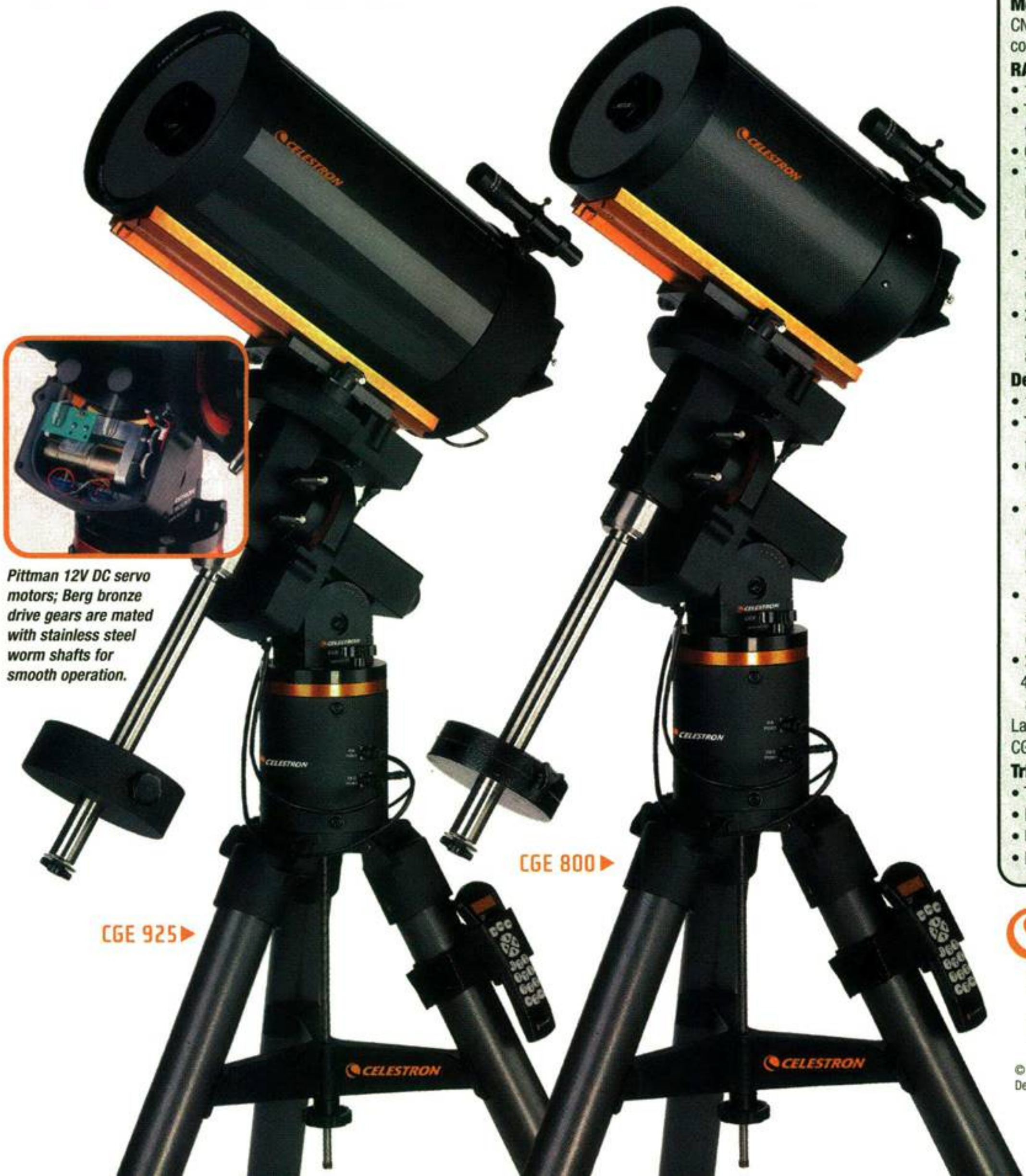
Declination axis

- 1" solid ground stainless steel shaft
- Two Pre-loaded .9835" I.D. x 2.047" O.D. tapered roller bearings
- One 3.250" O.D. x 2.500" I.D. thrust bearing
- 180 tooth, 5.625" diameter enveloping bronze gear preloaded to maintain gear mesh while clutch tension varies, manufactured to AGMA 10 quality.
- .4375" diameter precision 303 stainless steel worm, manufactured to AGMA 10 quality
- 2 point Dec clutch system pre-loading a 4.65" stainless steel disk for no-slip drive and pointing precision

Latitude Range: 10° to 60°
CGE Maximum Payload: 65 lbs.

Tripod

- Tripod height: 36" to 50"
- Leg material: cold rolled carbon steel
- Upper leg diameter: 2.75"
- Lower leg diameter: 2.375"



Pittman 12V DC servo motors; Berg bronze drive gears are mated with stainless steel worm shafts for smooth operation.

CELESTRON

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"We ran through the alignment procedure during evening twilight and observed throughout the entire night without missing a beat...and every object that we commanded the scope to point at ended up in the field of a low-power eyepiece."

"The optics in the NexStar loaned to us were some of the finest I can recall in a Schmidt-Cassegrain, but if anything the optics in the scope we purchased at random were even better."

–Dennis di Cicco
"The NexStar 11 GPS: Beauty and Brains"
Sky and Telescope
February 2002

A telescope that combines the design features, engineering, performance, and value of the NexStar® 11GPS doesn't come out of the *Blue*.

CELESTRON
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NexStar® 11GPS
$2999*
+ $125 Shipping & Handling
Includes Standard Heavy-Duty Adjustable Tripod

At Celestron, we know that the whole is greater than the sum of all of its parts. That's why we design, engineer, and manufacture the NexStar 11GPS telescope from the beginning with features and performance that add up to a whole lot more telescope than the competitor's 8", 10" and 12" GPS telescopes — ***and a better value.***

Here's why: Compare the design features and construction of the NexStar 11GPS (as well as the NexStar 8GPS) to the competitor's 12", 10", and 8" GPS telescopes. Every component of the NexStar 11GPS, from its rugged integrated drive base and fork arm design to the unique carbon fiber optical tube assembly has been designed specifically for this model NexStar telescope. Only Celestron matches and meticulously hand-figures each individual telescope optical system.

Understanding Resolution.

Do coatings affect resolution? No! When comparing telescopes, it's extremely important to clearly understand the relationship between coatings and resolution. ***Fact: Resolution is a function of aperture. Coatings only affect light transmission.*** It is a function of aperture or diameter of the objective lens. Rayleigh's Criterion defines resolution as: $\theta=1.22*\lambda/D$, where λ is the wavelength of light, D is the diameter of the objective lens, and θ is the resolution in radians. Image brightness is a function of aperture, focal ratio, and system's light transmission efficiency. ***StarBright® coatings have been standard on all of our Schmidt-Cassegrain telescopes since 1983 AT NO ADDITIONAL COST.*** For primary and secondary mirrors, StarBright coating is a precise multilayer application of Al, SiO_2, TiO_2, and then another layer of SiO_2 — all to maximize reflectivity. On the corrector lens we apply precise layers of MgF_2 to both surfaces to maximize transmission.

The dark-adapted (scotopic) eye's peak sensitivity is at 510nm. The sensitivity drops off dramatically on either side of 510nm. In fact, as the wavelength approaches 400nm, the eye's sensitivity goes to almost 0%. The same is true as the wavelength goes to 600nm. Celestron's StarBright® Coatings are designed to peak at 510nm, the peak sensitivity of the scotopic eye. Celestron offers these coatings at no additional cost to the consumer. The chart below shows the transmission at 510nm for both Celestron and competitor's large aperture SCT telescopes.

Transmission at 510nm for all Celestron large aperture SCT's and competitor's SCT's

NexStar 8"	87%	No Additional Cost
NexStar 9.25", 11", 14"	85%	No Additional Cost
Competitor's Standard Coatings - all SCT's	77%	No Additional Cost
Competitor's UHTC	86%	Cost: $175 (8"), $235 (10"), $295 (12")

Competitive information obtained from December, 2002 issue of *Sky and Telescope*.

NexStar 11GPS. Quality from the inside out.

Carbon Fiber Tube — Strong and lightweight with 1/4 of the thermal expansion of an aluminum tube. Scratch and dent resistant.

Optical Tube Assembly Outer Rails — An outer rail on each side of the optical tube provides rigid, flex-free movement. Mounting tolerance allows cell to contract and expand.

NexStar quality and reliability. Designed in. Not added on.

COMPARISON OF DESIGN FEATURES

This chart compares the significant design and engineering features of the NexStar 11GPS with competitor's 10" and 12" GPS telescopes.*

Feature/Specification	NexStar 11GPS	Competitor's 10"	Competitor's 12"
Mirror Coatings	StarBright*; 5-step multilayer	Standard; (Enhanced Coatings $235)	Standard; (Enhanced Coatings $295)
Fork Arm	Dual fork tine cast aluminum with integrated hand control receptacle. Fork arms are long enough to permit optical tube to swing through	Dual fork tine cast aluminum; hand control attaches to fork arm with external bracket.	Dual fork tine cast aluminum; hand control attaches to fork arm with external bracket; fork arms not long enough to allow optical tube to swing through
Leveling Technique	Internal switch - levels the tube to the mount to the accuracy of 1 arcminute; Usable for both Alt/Az and equatorial	Ground level switch; only useful for Alt/Az	Ground level switch; only useful for Alt/Az
Cord Management	Internal slip ring design. Power is mounted to non-rotating part of drive base. Accessory ports rotate with top of drive base	Requires internal hard stops to avoid tangling and disconnecting wires; accessory ports do not rotate with telescope which can cause cords tangling	Requires internal hard stops to avoid tangling and disconnecting wires; accessory ports do not rotate with telescope which can cause cords tangling
Carrying Handles	Ergonomically designed for ease of lifting	Attached to front of fork arms	Attached to front and back of fork arms
Motors	Pittman mfg. in U.S.A.;12V DC Servo; quiet	Unknown; very noisy	Unknown; very noisy
Gears	Berg mfg. in U.S.A.; 5.625" precision bronze gears on both axes; 180-tooth; mated with stainless steel worm shaft	5.75" aluminum gears on both axes	5.75" aluminum gears on both axes
Bearings	9.5" roller azimuth bearing	4" dia. polar bearings	4" dia. polar bearings
Focusing Mechanism	Two (2) preloaded ball bearings	Bushing and washer	Bushing and washer
Optical Tube	Carbon Fiber; reduces thermal expansion; 4x less than aluminum	Aluminum	Aluminum
Fastar Compatible	Yes	No	No
Weight of Telescope	63 lbs.	62 lbs	75 lbs
GoTo Precision	1.5 arcminutes	2 arcminutes	2 arcminutes
Boot-up Time	1-1.5 sec.	20-25 sec.	20-25 sec.
GPS Alignment Time	2.5 min.	More than 4.5 min.	More than 4.5 min.
Quick Align	Yes	No	No
Database Filter Limits	Automatic filter limits for named objects list	No database filter limits for custom object lists	No database filter limits for custom object lists
Price**	**$2,999 + $125 S&H = $3,124**	**$2,495 + $145 S&H + $235 for Enhanced coatings = $2,875**	**$2,995 + $215 S&H + $295 for Enhanced coatings = $3,505**

How you can tell wrong from right.

Celestron strongly believes that the only way to design and manufacture our NexStar GPS telescopes is the ***right way***. The right way means understanding what expectations our customers have when they make an investment in our products, and designing and manufacturing telescopes that meet or exceed their expectations. That means paying attention to details and not cutting corners. Compare the following examples of why we believe that we have designed the NexStar 8GPS and 11GPS the right way and what we believe is wrong with the design of the competitor's GPS telescopes. Consult the chart to the left for an additional comparison.

Their Way:

- The competitor's GPS antenna is partially obstructed by the finderscope.
- When the base rotates, cables can easily wrap around the fork arms and become entangled.
- Carrying handles are poorly designed and located making it difficult to lift the telescope.
- Boot-up time can take as much as 20-25 sec.
- Hand control displays objects below the horizon.
- Motors and gearbox are noisy.
- The competitor's 10", and 12" drive base is undersized.
- The OTA (Optical Tube Assembly) on the competitor's 12" will not swing through and clear the drive base; the fork arms have spacers to attach to the base.
- The complete optical system is not hand-figured.
- The hand control is attached to a bracket with the cable hanging loose.
- Enhanced optical coatings cost extra
- Focus mechanism uses bushings intead of ball bearings.

Our Way:

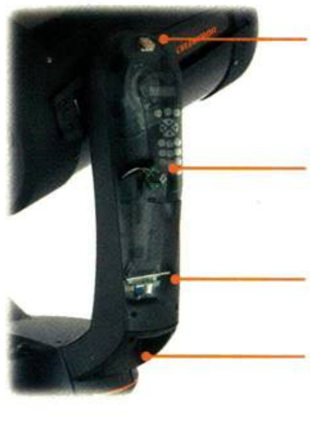
- Celestron's GPS antenna is not obstructed by the finderscope.
- Celestron's drive base design eliminates any potential for cord/cable wrap.
- Carrying handles are integrated into fork arms to make lifting and transporting easier.
- Boot-up and alignment are fast and easy.
- Hand control has many advanced features and is user-friendly; only shows objects above the horizon.
- High quality precision gearing ensures quiet, precise operation.
- Large diameter drive base and bearing track provides maximum stability. Especially important when equatorially mounted.
- Carbon fiber tube minimizes thermal expansion/contraction; important for astrophotography or CCD imaging.
- Mirror shift minimized through use of precision bearings.

* Version Tested: 1.0b Telescope Serial #01039 All comparative information obtained from User Manual for this model.

**Prices obtained from December, 2002 issue of *Sky & Telescope*

Set-up Information: Starting Position: Alt.= -90 and Az =0

Date: 09.18.02 Time: 8:00 PM (no daylight savings) Long: 118 West Lat: 34 North

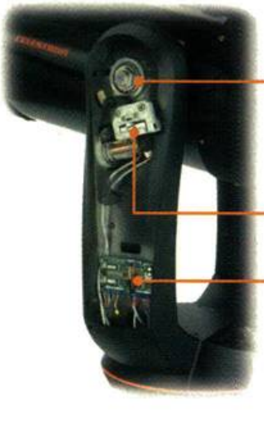


***16-channel GPS* — Interference free. Finderscope is positioned away from GPS antenna. Pinpoints your exact location on Earth with an unobstructed view.**

***Upgraded hand control and software features* — 40,000 object database; new features include compass calibration, polar alignment routine, EQ AutoAlign, database filter limits, hibernate, Auto north and level, wedge align algorithm, Quick Align, user-defined slew limits.**

***Electronic compass* — Finds true North when used in conjunction with NexStar software.**

***Ergonomically designed fork arm with integral handles* — Integrated handles in fork arms designed for ease of carrying and safe and easy setup and transportation.**



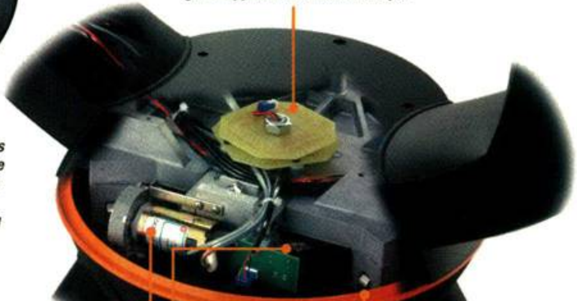
***Bearing and shaft* — Heavy-duty preloaded tapered roller bearing on both axes.**

***Worm shaft* — Stainless steel worm shaft has .4375 pitch diameter and is preloaded with two ball bearings. The worm is made from a single piece of steel to minimize run-out, which is the source of periodic error.**

***Heavy-duty aluminum spring loaded worm block* — On both axes; minimizes backlash.**

***Motor board* — Each axis is controlled by its own 8-bit microcontroller.**

***Auxiliary Ports* — The NexStar's auxiliary ports are located on the top of the base which rotates as the telescope turns preventing accessory cables from wrapping around fork arms.**



***Internal Slip Ring* — The NexStar's power cables will never wrap and telescope accessory cables will not get wrapped around the telescope.**

***Drive Motors* — Made in the U.S.A., Pittman Lo-Cog™ brush commutated DC motors offer smooth, quiet operation and long life. The motor armatures are skewed to minimize cogging which is required for low speed tracking. Windings are resin impregnated for greater reliability in incremental motion application.**

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ARIANESPACE AND ESA have announced the postponement of the launch of the Rosetta space probe, with possible new launch dates in late 2003 or early 2004. Rosetta is designed to land on a comet.

news 05

Read all about it: Shredded dwarf galaxies, the age of reionization, extrasolar planet searches, the Milky Way's magnetic fields, and a jetting spiral.

BUSH FIRES

Mt. Stromlo Observatory destroyed in fires

On January 19, bush fires destroyed Mount Stromlo Observatory's seven telescopes, its workshops, and the homes of astronomers, students, and support staff living on-site. Research School Director Penny Sackett says, "Our losses are presently overwhelming and the scene of Mt. Stromlo is one of devastation, but we have retained our most valuable asset, our staff, 100 percent intact and we are extremely grateful for their safety."

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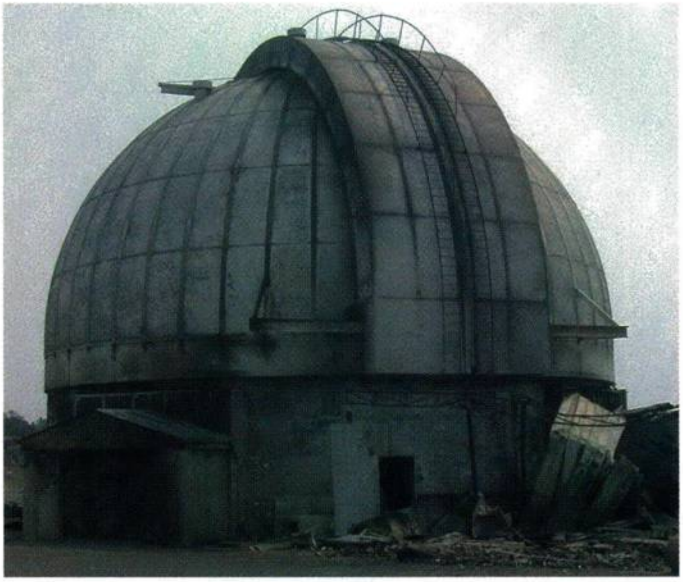
Telescopes destroyed include: the circa 1911 9-inch Oddie Refractor, the Commonwealth Solar Telescope, the 26-inch Yale-Columbia refractor, the 30-inch Reynolds reflector, the 50-inch Great Melbourne Telescope, the 74-inch Grubb-Parsons reflector, and the EOS laser ranging facility.

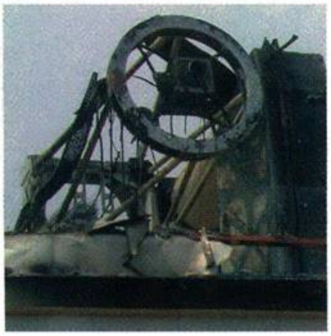
The workshops containing a new spectroscope being constructed for the 8-meter Gemini North Telescope were also destroyed, as well as the administration building and the observatory library. Remarkably, the visitors' center and two other office buildings, the Duffield and Woolley buildings, survived with water damage. Also, no computer data was lost.

Australian National University Vice-chancellor Ian Chubb emphasizes, "The University has adequate workshop and laboratory facilities to accommodate the valuable equipment contracts which are being fulfilled by the school — including the $6.3 million contract to build a sharp-eyed imager for the Gemini South Telescope in Chile . . . The fires have been a devastating blow to Canberra, and the ANU is committed to helping rebuild the lives of those affected." There are plans to rebuild the observatory as quickly as possible, with EOS hoping to be back up in less than 6 months.

Tax-deductible donations to help the families and the observatory rebuilding can be made at: www.anu.edu.au /fires/relief.php — **PAMELA L. GAY**



THE 74-INCH GRUBB-PARSONS TELESCOPE was flash-incinerated when a 35-km-wide swath of fire overwhelmed the observatory. Now an ashen shell, this dome at least maintained its shape. M. COLLESS, RSAA, ANU



THE GREAT MELBOURNE TELESCOPE, a 50-inch reflector, stares blindly into the smoke-filled sky. The telescope was one of the observatory's most historic pieces. M. COLLESS, RSAA, AUSTRALIAN NATIONAL UNIVERSITY

ICESAT AND CHIPS – the NASA Ice, Cloud and Land Elevation satellite and the Cosmic Hot Interstellar Spectrometer satellite – successfully launched from Vandenberg Air Force Base, California, on January 12 aboard a Boeing Delta II rocket.

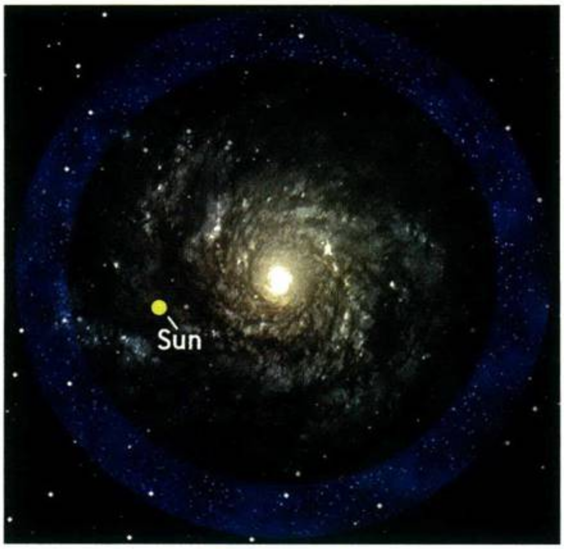
MILKY WAY

Shredded dwarfs

Galaxies grow via the merger of smaller systems into larger and larger systems. Dust builds into planets. Small galaxies build into larger galaxies, and, on larger scales, galaxy groups build galaxy clusters. New evidence brings home the cannibalistic habits of our own galaxy. Astronomers using the Sloan Digital Sky Survey (SDSS) found a ring of material around the Milky Way that they believe formed when a small galaxy was shredded by our galaxy's gravitational pull.

The SDSS is mapping one-quarter of the sky in detail. While studying the distribution of objects in the SDSS, astronomers discovered an unexpected overdensity of stars beyond the edge of our galaxy. With orbits tracing out a region shaped like a celestial donut, these objects are not part of our galaxy's disk or halo populations. Their tight orbital distribution indicates they are the remnants of a destroyed dwarf galaxy.

"When we find large groups of stars formed into rings, it's an indication that at least part of our galaxy was formed by a lot of smaller or dwarf galaxies mixing together," explains project scientist Heidi Jo Newberg, an astronomer at Rensselaer Polytechnic Institute. **— P. L. G.**



RINGED BY DISRUPTED GALAXIES, the Milky Way wears the carnage of its too-close-encounters with dwarf galaxies. A disrupted unknown system rings the disk, while the remnants of the Sagittarius dwarf galaxy form an inclined ring. KECK/GALILEO

EXTRASOLAR PLANETS

Transit discovery

The first planet found via stellar transits has been discovered. Named OGLE-TR-56b, it orbits a mere 0.02 AU from its parent star. With a period of just 29 hours, it has the smallest and fastest known orbit.

Stellar transits occur when planets pass between Earth and their host stars, effectively eclipsing part of the star's light. Repeated dimmings reflect the orbital period of the planet.

The Optical Gravitational Lensing Experiment (OGLE) survey detected 12 transits of the star OGLE-TR-56. Eight additional spectroscopic velocity measurements fit on a curve predicted by the transit timings. These spectra suggest a planet size of 0.9 Jupiter masses.

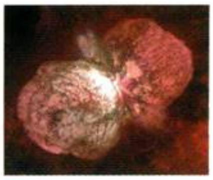
Several known extrasolar planets have periods of a few days, but none are as quick as OGLE-TR-56b. This tiny orbit is surprising because theories suggest it should be devoured by its host star. The OGLE data contains a second planetary candidate with similar orbital characteristics. — TOM FORD

BINARY STAR

Eta Carinae may have a partner

Outbursts from the variable Eta Carinae were once thought to be random episodes from an unstable giant, but over the past decade astronomers have found a pattern in the bursts. They believe they are caused by clashing stellar winds from massive binary stars.

Michael Corcoran of NASA's Goddard Space Flight Center led a team that monitored x-ray radiation from Eta Carinae using the Röntgen satellite and Rossi X-ray Timing Explorer. Over ten years they confirmed previously observed x-ray fluctuations and found a 5.52-year emission pattern.



ETA CARINAE flared up and formed expanding lobes 100 years ago. J. MORSE / NASA

"If Eta Carinae is in fact two stars, the x-ray output should vary with the orbital period of a smaller star revolving around a larger star in each cycle, and this is in fact what we see," Corcoran explains.

The group suggests that a 30-solar-mass star orbits an 80-solar-mass star in an elongated, 5.52-year circuit that brings the stars as close as 5 astronomical units and as far apart as 30 AU. **— VANESSA THOMAS**

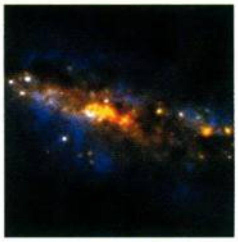
STAR CLUSTERS

Forming globulars

Astronomers studying the nearby starburst galaxy M82 have found what may be newly forming globular clusters.

"This is very interesting because globular clusters are the oldest objects in our own galaxy and we don't know how they formed," says Nate McCrady, lead author on this project. "The clusters in M82 give us a chance to watch the formation process as it occurs." Milky Way globular clusters are 12 to 15 billion years old, while the clusters in M82 are just 10 million years old.

Clusters MGG-9 and MGG-11 in M82 are about 10 light-years in diameter and contain millions of stars with the highest stellar densities in the clusters' cores. Unlike local globulars, M82's clusters are rich in large, hot stars. The formation of these globulars, as well as other star formation in M82, may have been triggered by gravitational interactions with M81 100 million years ago. **— P. L. G.**

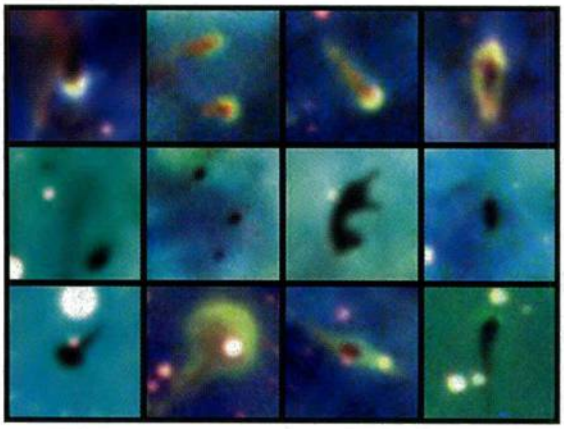


STARBURSTING M82 contains what may be newly forming globular clusters. NATE MCCRADY, UC BERKELEY

A PLANET IN PERIL WAS DISCOVERED around HD 47536. This giant star is near the end of its main sequence life and will swell to engulf its new found world within a few tens of millions of years. The same fate awaits Earth in several billion years.

STAR FORMATION

Evaporating proplyds



STELLAR COCOONS EVAPORATE under the glare of nearby hot stars in the Carina Nebula. Like comets, their tails point away from the stars that radiate them. UNIVERSITY OF COLORADO / NOAO / AURA / NSF

Deep inside nebular cocoons, young stars collapse into life and planets form. Astronomers have now discovered dozens of these cocoons, technically called proto-planetary disks or proplyds, in high-resolution images of the Carina Nebula that were taken with Cerro Tololo's 4-meter Blanco telescope. This is the second nebula found to contain proplyds. The other, the Orion Nebula, was observed with the Keck in Hawaii and the Hubble Space Telescope.

"These intriguing proto-planetary systems in the Carina Nebula are located near several of the hottest and most massive stars known in the Milky Way," says Nathan Smith of the University of Colorado, lead author on the Carina study. "This suggests that planetary disks may be more resilient or more common than previously thought."

Over time, radiation from hot stars evaporates the cocoons that surround young systems. This gives proplyds comet-like shapes — round heads with tails pointing away from nearby hot stars.

According to UCLA's Mark Morris, who studies the Orion Nebula, "We're literally watching these disks evaporate before our eyes as the overwhelming energy of the nearby hot stars bears down on them."

"Most normal stars like our Sun form in violent 'starburst' regions with much more massive stars — an environment more like the Carina Nebula than Orion," Smith says. "A better understanding of these objects in Carina should tell us more about the prospects for survival of early planetary systems." This will allow better statistics on planet formation rates to be determined. **— P. L. G.**

GALAXY SURVEY

HIPASS

Putting an astronomical spin on "two heads are better than one," the Australian Parkes radio telescope scans the sky for neutral hydrogen gas (HI) with a 13-beam receiving system. Thirty-four researchers from Australia, Europe, and the United States used Parkes to make the first complete survey of HI in the southern sky. Called HIPASS (HI Parkes All Sky Survey), this survey produced the first complete picture of the distribution of mass in the local universe free of the presence of stars.

According to the project's leader, Rachel Webster, "This is the first truly unbiased, large-scale survey of neutral hydrogen in the local universe."
— MATT QUANDT

HIPASS detected 100 times more HI than any previous survey. J. MASTERSON (CSIRO)

COSMOLOGY

Unveiling the universe

Scientists have found 26 of the galaxies responsible for making our young, cloudy universe transparent.

After the Big Bang, the universe was an opaque particle soup. Three minutes later, it had cooled enough for energy (photons) and matter (electrons and protons) to de-couple, and for atomic nuclei to form. The universe was now ionized and transparent, but there was nothing to see.

Over time, the universe again became opaque, plunging into a billion-year dark age as it cooled, and electrons bonded with nuclei to form clouds of neutral gas.

This gas became the building material of the first stars. Their light then reionized much of the remaining interstellar hydrogen, reseparating electrons from nuclei and making the universe again transparent.

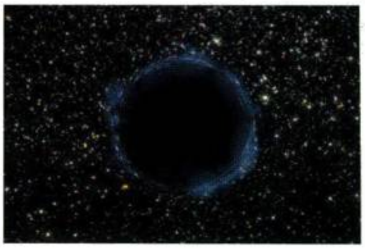
BY IONIZING GAS, these galaxies ended the universe's "dark age." NASA, YAN ET AL. (ASU)

An Arizona State University team identified 13 billion-year-old, star-forming galaxies that took part in this reionization process in a dark corner of Virgo. Hao Jing Jan explains, "The 26 we've observed are merely the tip of the iceberg." **— T. F.**

EVOLUTION

The black hole, then the stars

Which came first? The galaxy or the black hole? Those debating this astronomical chicken-or-the-egg question have new evidence to consider. A study of several hundred young, active galaxies in the distant universe reveals that, although they're still developing, each observed galaxy already has a fully formed supermassive black hole at its core.



SUPERMASSIVE BLACK HOLES may have formed earlier than the galaxies that surround them. NASA / G. BACON (STScI)

According to Ohio State University researcher Marianne Vestergaard's survey of quasars, approximately 12 billion light-years away, supermassive black holes form and grow by accreting material in the dense cores of existing galaxies.

"Looking at this evidence, I have to think that black holes start forming before galaxies do, or form at a much faster rate, or both," Vestergaard says. **— V. T.**

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Optional Computerized Hand Control: $149
Optional Tripod: $149

NexStar® 5i

NexStar 5i shown with optional Computerized Hand Control, Tripod, and optional accessories for astrophotography.

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NASA'S SOLAR RADIATION AND CLIMATE EXPERIMENT (SORCE) successfully launched aboard a Pegasus XL rocket on January 25, 2003. This satellite will measure how the Sun affects the ozone layer, atmospheric circulation, clouds, and oceans.

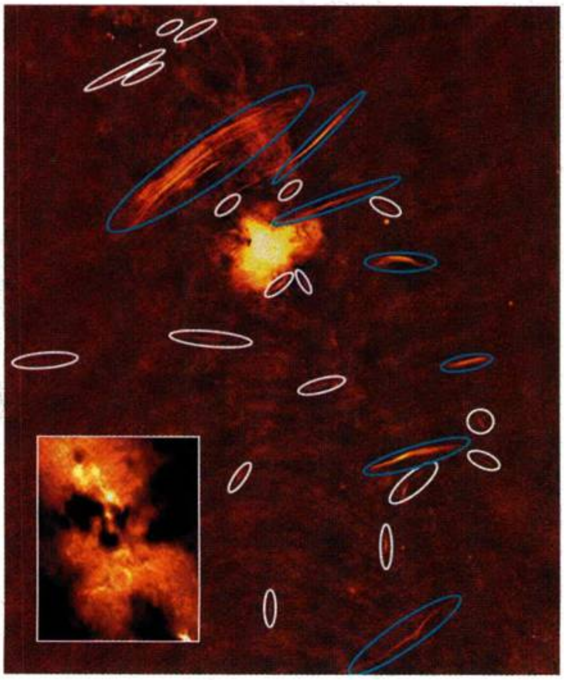
MILKY WAY

Spaghetti fields

Naval Research Laboratory astronomers have tripled the amount of filament-like structures imaged in the center of the Milky Way Galaxy. Using the Very Large Array Telescope, they cut through the ionized hydrogen that blocks visible light and imaged the galactic center in 1-meter and 4-meter radio wavelengths.

The filaments, or threads, are created by the interaction between ultra-high velocity electrons and a magnetic field, but since they've only been observed in the center of our galaxy, little else is known about them. Unlike the threads first discovered in 1984, they don't all point in a similar direction. Instead of displaying parallel arcs as Earth's magnetic field does, the data suggests a field that resembles a bowl of spaghetti.

Namil Kassim, one of the leaders of the team, says, "The Milky Way's center is an exciting, mysterious region that, once again, has given us a surprise." **— T. F.**



NEWLY DISCOVERED FILAMENTS (white ovals) in the center of the Milky Way aren't aligned the way astronomers expected in this 1-meter wavelength image. The first filaments (blue ovals) found suggested the galaxy's magnetic field was similar to Earth's. **4-METER RADIO WAVES** (inset) are blocked by foreground clouds of ionized hydrogen but help build a 3-D map of the galactic center. NRL

INSTRUMENTS

HIRES improved

A new advanced detector increases the Keck High Resolution Echelle Spectrometer's (HIRES) detection capabilities. This detector upgrade gives HIRES a much-needed shot in the arm to preserve its position at the forefront of extrasolar planet discovery.

THE KECK TELESCOPE sports the new and improved HIRES. UCSC AND W. M. KECK OBSERVATORY

"This upgrade will bring HIRES into the 21st century and keep this instrument competitive with its peers in producing some of the world's best optical spectra," says Frederic Chaffee, director of Keck Observatory.

The new detector increases HIRES's ultraviolet sensitivity by a factor of eight and has faster readouts, yielding higher-quality science in less time.— M. Q.

SPACECRAFT

To the Moon or bust

The first commercial Moon probe came a step closer to launch on December 20, 2002 when a Russian rocket carried a mass/size mockup into Earth orbit. With the launching of the actual Trailblazer lunar orbiter planned for October of this year, that success of getting hardware into space brought credibility (and needed funding) to the sponsor, Transorbital Corporation.

A combination of advanced lightweight space systems and the availability of converted Russian military missiles makes this project feasible. The Dnepr rocket will be launched from Russia's Baykonur Cosmodrome in Kazakhstan. The lunar vehicle will weigh 420 kg in parking orbit, including its booster, and will be able to insert a 100-kg payload into lunar orbit.

TRANSORBITAL plans to place their commercial Trailblazer in orbit in 2003. TRANSORBITAL, INC.

The Trailblazer will carry cameras capable of resolutions better than 1 meter – fine enough to identify vintage Apollo mission hardware. Commercial applications include impacting mementos and cremated remains on the lunar surface. **— JAMES OBERG**

SUPERMASSIVE BLACK HOLES

Lobed monster in Sagittarius

The Chandra x-ray satellite has observed the Milky Way's central black hole, Sagittarius A*, for two weeks (164 hours) and recorded its day-to-day behavior.

SAGITTARIUS A*, the supermassive black hole in the center of the Milky Way, regularly outbursts in x ray, and has lobes and a jet. CHANDRA ACIS

"We are getting a look at the everyday life of a supermassive black hole like never before," says astronomer Frederick Baganoff of MIT.

Along with more than a dozen high-energy outbursts, researchers detected faint x-ray jets nearly 1 light-year long and lobes of 20-million-degree Celsius gas.

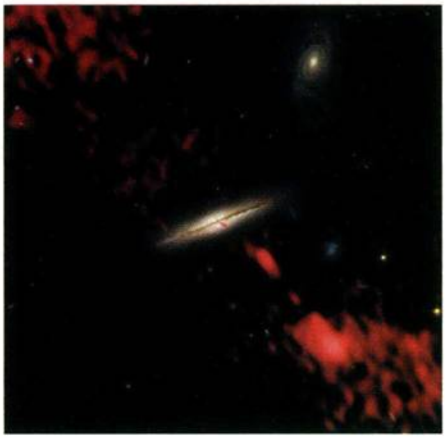
These high-energy phenomena are associated with activity near the event horizon of the black hole. "These lobes show that enormous explosions have occurred several times over the last ten thousand years," says Mark Morris of UCLA, lead author on this work.

The jets and x-ray outbursts are generated by material falling toward the black hole and were *much more common* in the past. **— P. L. G.**

HIGH ENERGY

A jetting spiral

Powerful magnetic fields riddle the cores of galaxies. Infalling material can get trapped in these fields and accelerated out of the systems in high velocity radio jets. Until recently, all known jets were associated with elliptical galaxies. Now, astronomers using the Very Large Array in New Mexico and the Hubble Space Telescope have found a very unusual pair of jets that originates in the heart of the spiral galaxy 0313–192.



JETTING 0313–192 is the first spiral galaxy observed to have radio jets. KEEL ET AL, STScI, NRAO, NASA

"We've always thought spirals were the wrong kind of galaxy to generate these huge jets, but now we're going to have to rethink some of our ideas on what produces these jets," says William Keel, a University of Alabama astronomer who led the research team.

Spiral 0313–192 is located in Abell 428, a loose collection of galaxy groups that form a cluster. In this environment, 0313–192 has undergone interactions with other galaxies.

"This galaxy's disk is twisted, and that may indicate that it has been disturbed by a close passage of another galaxy or may have swallowed up a companion dwarf galaxy," Keel says. This recent encounter may partially explain the jet. Further study, and other examples, are needed to understand this new morphology/jet combination. — **P. L. G.**

What could be worth the price of a space shuttle crew?

Faced with the horror of a high-priced spaceship and seven priceless lives being destroyed over Texas, the question arises — what's this science stuff the Columbia crew was doing that needs such sacrifices?

Those of us in the astronomy community — professionals, amateurs, communicators, dabblers — can uniquely answer these questions. We know how to communicate our need to reach for the heavens. We've already been doing this with friends and family who sometimes regard our fascination with the unreachable stars as an idle pastime, a trivial luxury, or a marginal and irrelevant hobby.

But it isn't. Not now, and not ever. We know — and need to make the message clear especially in times such as these — that the human fascination with things above the sky has been the forcing function and the engine behind human progress, both technologically and intellectually.

Space exploration is the current manifestation of an aeons-old drive to grasp the heavens. Astronomy was for millennia the space exploration of its time. Aside from using the sky as a timekeeper and season predictor, people saw stranger things — such as the Moon and the planets — that made them think about how the sky worked. Curious about predicting celestial motions and the terrifying eclipses of both Sun and Moon, they developed higher mathematics along with better and better calculating technology. And when dogmas embraced by entire civilizations collided with stunning new theories of Earth's place in the universe, knowledge won and dogma lost.

It is for the forward-looking energizing forces created by scientific research, and the practical benefits as well, that we explore and tinker and invent. Societies that cling to a static past — the good old days — suffer, both as cultures and as individuals.

From the beginning, those human clans that survived and prospered were the explorers. The self-satisfied stay-at-homers went extinct, although we see even during the debates around this tragedy that at least some of their throwback traits reappear during periods of stress and fear.

STS-107 was on a mission of exploration — one uniquely suited to the advantages of human curiosity working on the frontier of human knowledge. It was one of the rare flights devoted to research, instead of to the International Space Station. Its mission was to identify scientific avenues appropriate for later exploration aboard the space station.

Without construction and maintenance to worry about, the Columbia crew did science in a density that ISS astronauts can't currently achieve. In 16 days, STS-107 scientists accomplished as much research as space station crews can get done in six months. Most of what they did can't be automated — human sensors (eyes) and effectors (fingers) were required.

They were at the point-of-the-spear of civilization, and we are proud that there are people like them among our fellow earthlings, and that there are enough people like us willing to support their activities to make human space flight possible. More like them will step forth to take their places, for which we can be prouder.

None of this means that we should rashly court danger for its own sake. Nor should we ever accept such losses as inevitable, since often they genuinely are the result of carelessness and oversight rather than the unavoidable hazards of the unknown.

As we never forget the hazards of exploration, we also must balance them against the even more terrifying hazards of not exploring. As long as fully informed explorers like those on Columbia are willing to fly to the heavens, we do have a future. — J. O.

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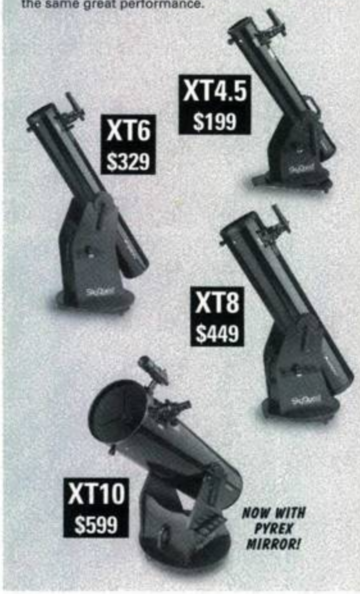

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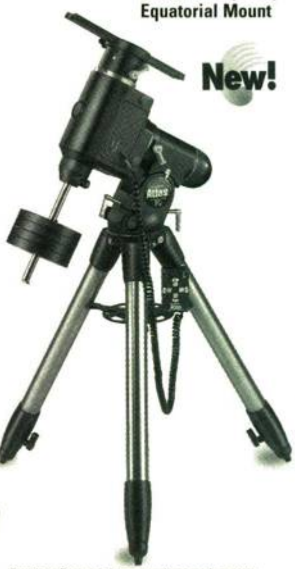

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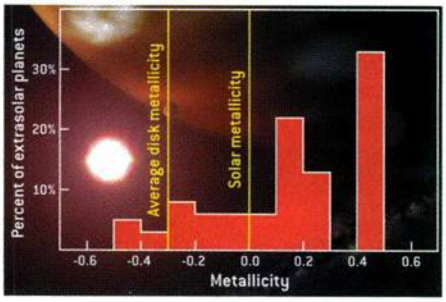
EXTRASOLAR PLANETS

Planets prefer metal-rich hosts

The roughly 100 planets known to orbit stars other than our Sun are quite different from those in our solar system. Nevertheless, a number of studies have confirmed an unexpected bond between those scattered systems and our own. Like the Sun, other stars harboring planets are richer in elements heavier than helium (metals, to astronomers) than the overall stellar population.

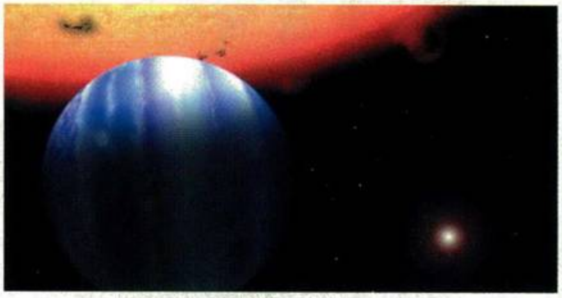


STARS ORBITED BY EXTRASOLAR PLANETS have a higher metal content, measured from their iron concentrations, than other stars. LAWS ET AL.

Why might we preferentially find planets orbiting metal-rich stars? Evidence suggests that planets may be more likely to form in metal-rich environs. Some stars, however, appear to have accreted metal-rich material in star-planet collisions long after their formation. It also remains possible — if unlikely — that planets formed in high metallicity places are larger and closer to their host stars and thus easier to detect.

If there is a tendency for metal-poor stars to lack planetary companions, planets may be very rare in large regions of our galaxy. The average metal content of stars in the halo is 100 times less than that of the Sun, and the disk-stars near our Sun have less than half the Sun's metallicity. Entire systems, such as globular clusters, are metal-poor. When 34,000 stars in the cluster 47 Tucanae were searched for planets, not one world was found. — **CHRIS LAWS**

Dim future for extrasolar planet searches



PLANETARY TRANSITS occur when an extrasolar world passes between its host star and Earth. D. A. AGUILAR, HARVARD-SMITHSONIAN CFA

The recent report of the first planet detected using the transit method implies a dim future for extrasolar planet searches — and that's a good thing. The transit method, which detects planets through the periodic dimming of starlight as a planet passes in front of its parent star, has the promise of uncovering enormous numbers of planets by increasing the volume of space that can be searched by a million or more. It may even yield the holy grail of extrasolar planet searches: the detection of earthlike planets around distant stars.

The transit search method has several advantages over the more well-known (and so far more successful) radial velocity method. First, large telescopes are not required to detect planets. Everyone from amateurs with small backyard telescopes to professionals with 8-meter behemoths can search for transiting planets with a reasonable chance of success. Second, planets can be detected around almost all types of stars. Stars much more massive and hotter than the Sun, as well as those that are smaller and cooler, can be searched. Finally, Earth-sized worlds should be detectable with future space telescopes such as the European Space Agency's Eddington mission or NASA's Kepler mission.

Achieving these results will not be easy. Transit searches are a gambler's nightmare: A Jupiter-sized planet orbiting 0.05 AU from a solar-type star has only a 10-percent chance of transiting its parent star. Even if it does so, it only dims its parent star about 4 percent of the time during the three days it takes to orbit. For earthlike planets, these numbers are even more frightening: The probability that an earthlike planet will transit its parent is closer to 0.5 percent, and the fraction of the planet's one-year period in which it dims the light of its sun is closer to 0.1 percent. To make matters worse, many objects look a lot like transiting planets, but aren't. They range from the mundane (like binary stars that just barely eclipse each other) to the insidious (like brown dwarfs with the same radius as planets) to the downright pathological (rare triple star systems, which seem almost designed to beguile planet searchers). These confusing "false positives" must be eliminated by careful target selection and detailed follow-up observations before planet detections can be considered real.

Nevertheless, the accessibility of transit searches is alluring, and the promise of great rewards has motivated many researchers to search for planets via transits. Currently, several dozen collaborations of professional and amateur astronomers are undertaking or planning transit searches. Over the next few years, we can expect to reap the bounty of these searches. The announcement of the first planet detected via transits thus heralds the beginning of an exciting, dim new age for extrasolar planets.

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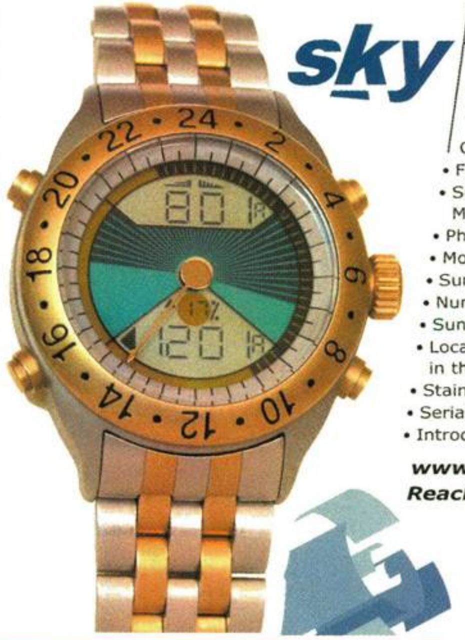

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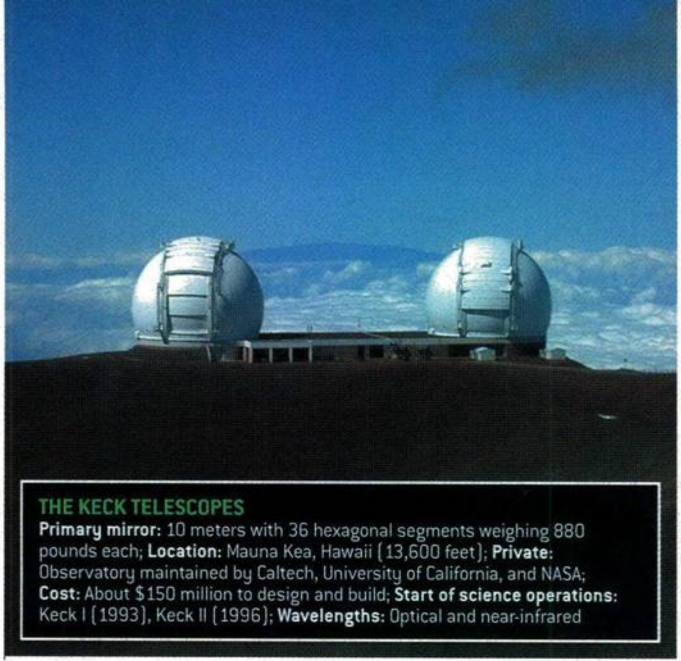
BIG glass

Today's giant telescopes leave the old 200-inch on Palomar Mountain in the dust. But for tomorrow, even bigger instruments loom. /// BY WILLIAM SCHOMAKER

For 45 years, the 5-meter (200-inch) Hale Telescope — the original "Glass Giant" atop California's Palomar Mountain — was the mighty king of all ground-based optical telescopes. It stood as a working monument to the power of Depression-era determination — not unlike its contemporaries, the Hoover Dam and the Golden Gate Bridge. ☾ But late last century, a new generation of Glass Giants began to take root on high and dry mountain peaks. There they scour the sky like visual time machines, opening portals to distant worlds and forgotten eras. These modern marvels, led by the twin 10-meter W. M. Keck Observatory telescopes in Hawaii, testify to the technological innovation and cyber sophistication at the turn of the century. ☾ With primary mirrors spanning 8 meters or more, these scopes dwarf the Hale Telescope in both aperture and scientific reach. And with the combined light-gathering power of a million pairs of human eyes each, they rival the performance of the best space observatories, yielding glimpses of the first

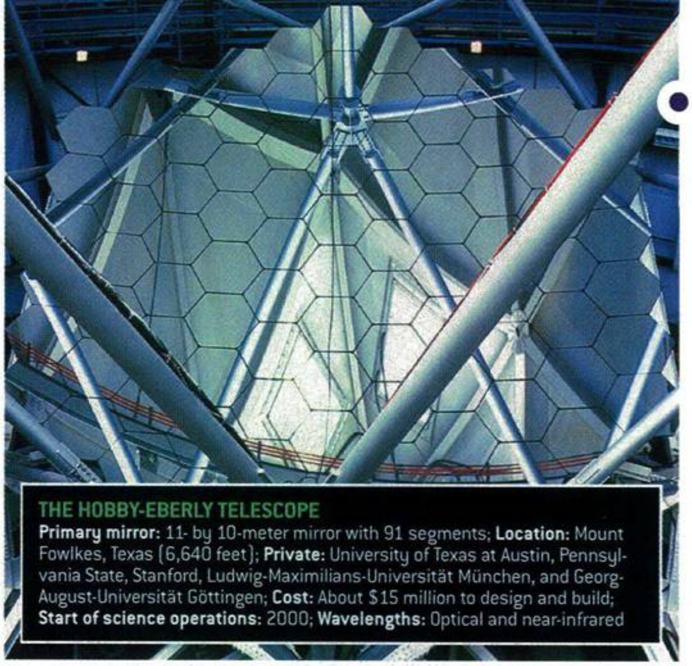
THE GEMINI SOUTH TELESCOPE on Chile's Cerro Pachon, one of ten new optical leviathans now probing the cosmos with ultra-sharp optics and gigantic collecting areas, prepares for a night of observations. NEELON CRAWFORD — POLAR FINE ARTS/AMNH/GEMINI OBSERVATORY



THE KECK TELESCOPES

Primary mirror: 10 meters with 36 hexagonal segments weighing 880 pounds each; **Location:** Mauna Kea, Hawaii (13,600 feet); **Private:** Observatory maintained by Caltech, University of California, and NASA; **Cost:** About $150 million to design and build; **Start of science operations:** Keck I (1993), Keck II (1996); **Wavelengths:** Optical and near-infrared

THE TWIN KECK TELESCOPES — the largest optical scopes on the planet — stand like sentinels on the summit of Mauna Kea. Precision actuators can align their mirrors to an accuracy of 4 nanometers. W. M. KECK OBSERVATORY



THE HOBBY-EBERLY TELESCOPE

Primary mirror: 11- by 10-meter mirror with 91 segments; **Location:** Mount Fowlkes, Texas (6,640 feet); **Private:** University of Texas at Austin, Pennsylvania State, Stanford, Ludwig-Maximilians-Universität München, and Georg-August-Universität Göttingen; **Cost:** About $15 million to design and build; **Start of science operations:** 2000; **Wavelengths:** Optical and near-infrared

THE UNIQUE DESIGN of the relatively inexpensive Hobby-Eberly Telescope, which keeps it pointed at a fixed altitude of 55°, makes it ideally suited for spectroscopic observations. MCDONALD OBSERVATORY

galaxies to be born, Saturn-sized extrasolar planets mere light-years away, rogue planets ripping through interstellar space, and individual stars caught in the death grip of a supermassive black hole at the heart of the Milky Way Galaxy.

These are the stories of the undisputed heavyweight champions of modern astronomy: the Top Ten largest ground-based telescopes and the five observatories they call home.

Hawaiian kings: the Keck telescopes

"When astronomers started daydreaming about 8- to 10-meter telescopes," says James Beletic, deputy director of the W. M. Keck Observatory, "there was a huge debate over whether you could really make a single-blank, 10-meter mirror."

Rather than wait for the debate to end, Keck developers opted for an unusual approach that allowed the observatory to crack the mega-telescope market nearly a decade ahead of the competition. In lieu of outfitting each of the twin scopes with a single, monolithic glass mirror, the developers sought ways to construct multiple, smaller mirrors and phase them together into a giant 10-meter mirror. Each of the mirrors ended up with 36 hexagonal segments that combine to create the world's largest mirrored surfaces for optical and near-infrared astronomy, with the light-grasp of four Hale Telescopes.

The Keck scopes share the peak of a dormant Hawaiian volcano named Mauna Kea with a dozen other world-class telescopes. These include two other Glass Giants profiled below — the 8.1-meter Gemini North Telescope and the 8.2-meter Subaru Telescope.

With 10-meter apertures, the Kecks are used to making headlines. University of California-Berkeley astronomer Geoff Marcy and his team of exoplanet hunters have made dozens of discoveries with Keck I since 1996. Today, Marcy's team is hot on the trail of lower mass planets with 10 to 40 times the mass of Earth.

"We have a sample of 700 stars that we're observing," he said during a recent Keck observing run. "That's such a large sample that we are going to find multiple planet systems *and* we're going to find the lowest mass planets *and* we're going to find planets that are orbiting far from their host star, reminding us of Jupiter and Saturn."

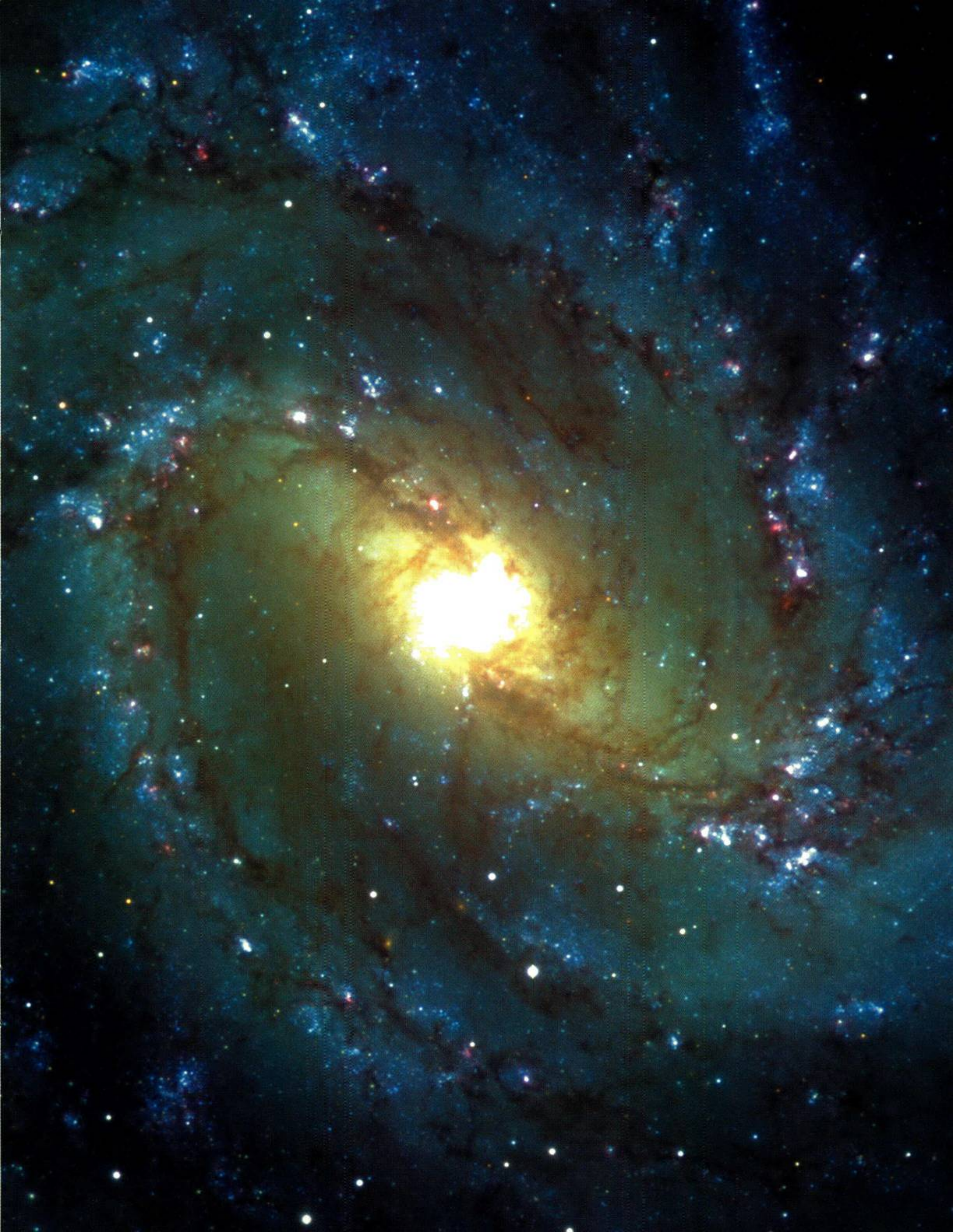
Meanwhile, the Kecks are so powerful that they often rely on other observatories for direction. Caltech astronomer George Djorgovski knows firsthand how this synergy works. In 2001 Djorgovski solicited help from the Sloan Digital Sky Survey and Keck II to take a long, hard look at the universe as it was 13 billion years ago — in the thick of the so-called "dark ages," when the universe was enveloped in a fog left over from the Big Bang. With a five-hour Keck II investigation of SDSS 1044–0125, a quasar in the constellation Sextans discovered by the Sloan survey, Djorgovski and his team collected the first telltale signs of the purported patchy, opaque fog from the quasar's spectrum.

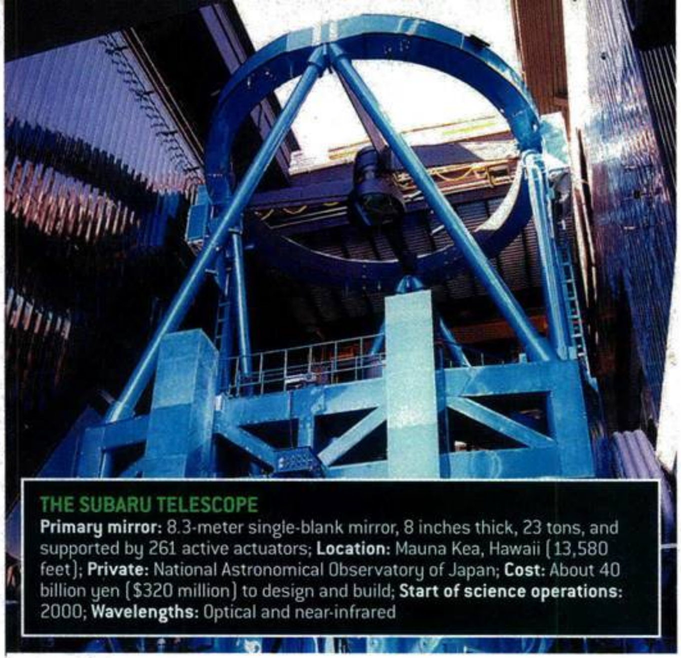
The observatory's largest challenge today is to maintain its position at the head of the giant-telescope pack. "When you compare Keck to facilities like Subaru and Gemini, which are relatively close in size, our light-collecting area is still 50 percent greater," says Beletic. "But an 8-meter telescope will beat a 10-meter telescope if it's more efficient."

Unlike newer big telescopes, the Kecks don't check their focus and image quality in real time. Instead, this requires a separate 15-minute routine that eats into valuable observing time. Like other modern telescopes, the 700,000-cubic-foot interiors of the Keck domes are chilled to the ambient nighttime temperature (32° Fahrenheit or 0° Celsius) during the day. But rather than sporting the sleek, silver enclosures of other observatories, the Keck domes are outdated, white

William Schomaker *is a contributing editor to* Astronomy.

DUSTY SPIRAL ARMS loaded with regions of active star formation wind around the older, yellowish core of the spiral galaxy M83, captured here by one of the four 8.2-meter telescopes of the Very Large Telescope. ESO

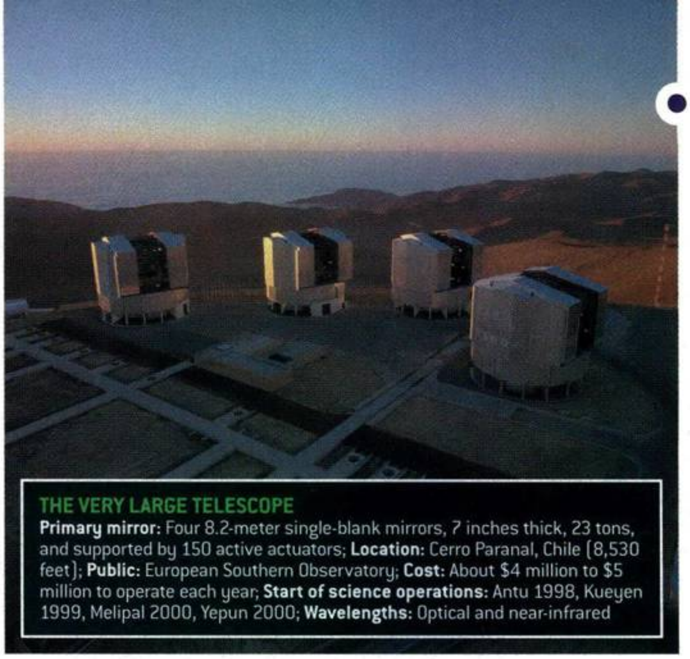




THE SUBARU TELESCOPE

Primary mirror: 8.3-meter single-blank mirror, 8 inches thick, 23 tons, and supported by 261 active actuators; **Location:** Mauna Kea, Hawaii (13,580 feet); **Private:** National Astronomical Observatory of Japan; **Cost:** About 40 billion yen ($320 million) to design and build; **Start of science operations:** 2000; **Wavelengths:** Optical and near-infrared

THE STATE-OF-THE-ART Subaru Telescope sports the largest single mirror in the world and a technologically advanced camera that can wring every last photon out of it. SUBARU TELESCOPE, NAOJ



THE VERY LARGE TELESCOPE

Primary mirror: Four 8.2-meter single-blank mirrors, 7 inches thick, 23 tons, and supported by 150 active actuators; **Location:** Cerro Paranal, Chile (8,530 feet); **Public:** European Southern Observatory; **Cost:** About $4 million to $5 million to operate each year; **Start of science operations:** Antu 1998, Kueyen 1999, Melipal 2000, Yepun 2000; **Wavelengths:** Optical and near-infrared

THE FOUR 8.2-METER TELESCOPES that make up the Very Large Telescope can operate either independently or in unison, a configuration that will give it the resolution of a 200-meter telescope. ESO

hemispherical structures that tend to dump cold air down into the dome, adversely affecting image quality.

Within the last three years the observatory installed fiber-optic audio and video links from the Keck headquarters in Waimea-Kamuela to the summit of Mauna Kea, eliminating the need for a trek to 14,000 feet to observe. As part of NASA's Origins program to identify and characterize possible earthlike planets around distant stars, the Kecks will be outfitted with new adaptive optics systems to improve their images. They will also be optically conjoined to create an interferometer, effectively producing an instrument with the resolution of an 85-meter mirror. And new instruments, such as DEIMOS — the largest focal plane optical or infrared spectrograph, capable of observing 150 objects at once — and OSIRIS — a near-infrared integral field spectrograph designed to obtain three-dimensional positions and spectra of extragalactic objects — could ensure the Kecks' first-place station for years to come.

Eye of Texas: the Hobby-Eberly Telescope

Straddling a mountaintop 450 miles west of Austin, there's a big telescope that fittingly belongs in Texas, but it defies just about every convention of modern telescope design. Like the Kecks, the giant Hobby-Eberly Telescope (HET) at McDonald Observatory carries a huge, 10-meter mirror comprised of hexagonal segments. But the HET is really more like the famous Arecibo radio telescope in Puerto Rico. It cranes up at the sky at a fixed 55° angle and is tailored toward spectroscopy.

It might seem wasteful to build a huge telescope that can't deliver stunning images or see more than 70 percent of the sky from its perch on Mount Fowlkes, yet the HET has found empty niches to fill. It can probe the properties of dark matter, as well as the temperature, velocity, rotation, and composition of celestial objects with unprecedented clarity. The HET is uniquely suited to study time-sensitive phenomena such as supernovae and star wobbles caused by extrasolar planets, where it becomes necessary to obtain spectral data at regular intervals. And perhaps most telling, it only cost a tenth of what it took to build the Kecks.

Still, the HET is a new telescope with its share of problems. Despite each of the 91 mirror segments having three precision actuators, the segments refuse to stay aligned for long. This is bad news for planet searches and detailed studies, which require a sharp focus. But other projects aren't hampered at all.

University of Texas astronomer Karl Gebhardt has been using the HET with unqualified success for three years now. Gebhardt studies the properties of dark matter in elliptical galaxies with the hopes of pinning down the script for how dark matter behaves during galaxy mergers.

"In the case of my project, HET is actually as efficient, if not more efficient, than any other telescope in the world," says Gebhardt. "I'm taking data on the Gemini scopes for the same project and HET is a little quicker." According to surprising preliminary results, Gebhardt's diffuse targets possess less dark matter than expected. Stay tuned for more details.

Perhaps more so than any of the other large new telescopes, the HET is a "queue observatory," in which observations are prioritized according to sky conditions and the order that targets pass through the telescope's field of view. In fact, there's no other choice. The HET's 85-foot geodesic dome can rotate 360°, but because of the telescope's fixed altitude, it can track objects for only about an hour before they are out of sight for the night. This means that work on many projects is completed each night by a team of resident astronomers rather than by visiting astronomers.

Engineers have recently attempted to improve the HET's imaging quality, including last year's addition of twenty-six 15-foot by 17-foot openings in the dome skin to encourage air circulation and equilibrium with outside conditions.

"Once the image quality comes along, HET will be a fantastic instrument," explains Gebhardt. "It's a really nice example of how to build a telescope on the cheap and still do some fantastic science."

Japan's gem: the Subaru Telescope

"It's a Cadillac facility," says University of Hawaii astronomer Brent Tully. "They've spared no expense when it comes to construction or instrument design."

With a 40-billion yen ($320 million) price tag, the National Astronomical Observatory of Japan's Subaru Telescope falls at the opposite end of the budget spectrum from the Hobby-Eberly. But it's been money well spent. Subaru (Japanese for Pleiades) sports the largest single-blank mirror in the world, one of the best imaging cameras around, a state-of-the-art enclosure, and an electromagnetic, friction-minimizing mount. (But notwithstanding Tully's sly reference, Subaru is not funded by the car company.)

Although it represents the pinnacle of new-generation telescopes, Subaru has been in the works since 1984, when the debate over building large single-blank mirrors was still raging. It took three years to produce the homogeneous 8.3-meter mirror blank made from ultra-low-thermal-expansion glass. And it took another four years to polish the mirror and prepare it for the 261 precision actuators that actively support its 8-inch-thick, 23-ton bulk. After extensive hydrodynamic tests and computer simulations, Subaru's designers settled on a novel cylindrical telescope enclosure that prevents air from entering while allowing warm air produced inside to escape rapidly. To ensure quality and consistency of construction, the telescope structure was preassembled in Japan before being shipped to Hawaii's Mauna Kea, where it stands next door to the Keck telescopes.

"These three factors contribute to Subaru's exceptionally high image quality: our mirror support system, the stiffness of the mechanical structure of the telescope mount, and the careful regulation of the daytime air temperature inside the enclosure," says Hiroshi Karoji, director of the Subaru Telescope.

When considering a deep, wide-field study of dwarf galaxies to gauge current dark matter theories last year, Tully was drawn to the imaging capabilities of the Subaru Suprime-Cam. "There's really nothing else like it on such a large telescope," he says. Suprime-Cam comprises ten CCDs and 80 million pixels nestled in the telescope's prime focus, 50 feet above the primary mirror. With a 20-inch corrector lens, the camera captures unprecedented wide-field exposures, 24 by 30 arcminutes (the size of a Full Moon). These are capable of uncovering Kuiper Belt objects at the edge of the solar system and the deepest secrets of galaxy structure.

Future plans for Subaru include a new adaptive optics system in 2005 and complete remote operation of the telescope from the Mitaka campus of the National Astronomical Observatory of Japan.

Four-in-one: the Very Large Telescope

Although the European Southern Observatory's Very Large Telescope (VLT) carries a prosaic label, there's much more to this innovative observatory. The VLT is actually the sum total of four 8.2-meter telescopes and a handful of 1.8-meter, movable auxiliary telescopes. Actually, make the "V"-for-"versatile." Sited high in the Chilean Atacama Desert, considered the driest place on Earth, each of the giant scopes can act alone, or in unison to yield the light-gathering power of a 16-meter scope, or in the VLTI interferometer phase to provide the resolution of a 200-meter telescope.

In 1985, the VLT consortium mandated that each unit telescope would be outfitted with a large, single-blank mirror, even though the technology didn't exist at the time. Eight years later, they had managed to produce the first of the modern single-blank mirrors, like those now found on Subaru and Gemini (below). The four unit telescopes are distinguished only by the instrument payload they carry. Each bears a Chilean Mapuche Indian name: Antu, Kueyen, Melipal, or Yepun. For example, Yepun is the only scope outfitted with an adaptive optics system. Otherwise, the mirror, support structure, and sleek cylindrical enclosure of each unit telescope are identical, making them ideal for working in concert.

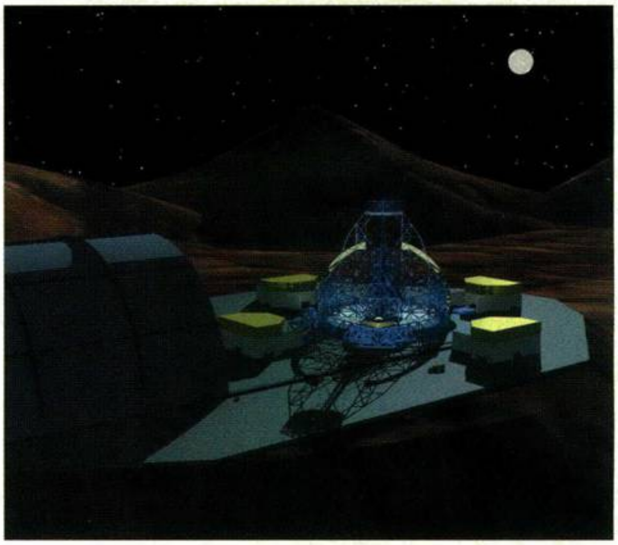
Late last year, an international team of astronomers applied the adaptive optics power of Yepun to the debate over what lies at the center of the Milky Way Galaxy. "We needed even sharper images to settle the issue of whether any configuration

/// BIG PLANS

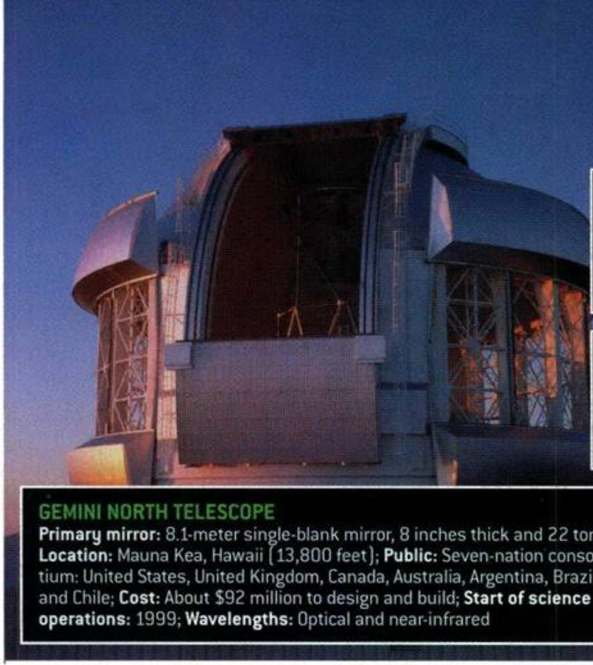
LARGE TELESCOPE PROJECTS ARE ON THE MARCH. A 10.4-meter scope, the Gran Telescopio Canarias, is being built in the Canary Islands. The South African Astronomical Observatory is building a 9.4-meter telescope based on the HET design. In the 8-meter range, the Large Binocular Telescope (with two 8.4-meter mirrors) is under construction on Mount Graham in Arizona.

Ahead lie proposed projects such as Canada's Very Large Optical Telescope (VLOT), a 20-meter instrument. Then there's the CELT (California Extremely Large Telescope) and the GSMT (Giant Segmented Mirror Telescope), both 30 meters in size. Stepping up is the MaxAT (Maximum Aperture Telescope) at 30 to 50 meters in diameter, and the Euro50, with a 50-meter aperture.

And that's not the limit. The European Southern Observatory is drafting detailed plans for a *100-meter* optical telescope. Appropriately, this gigantic instrument is known as the OWL — the OverWhelmingly Large Telescope. — *Robert Burnham*

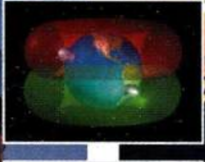


THE OVERWHELMINGLY LARGE TELESCOPE, a concept under study by the European Southern Observatory, would be a behemoth with an aperture of 100 meters. ESO

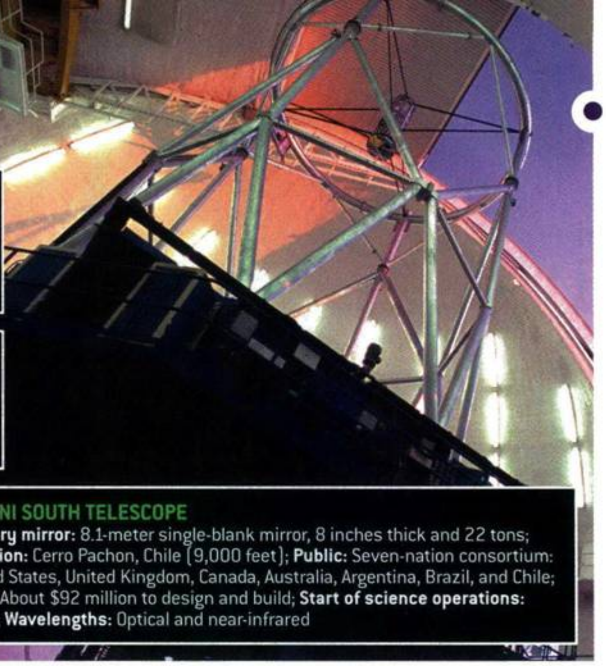


GEMINI NORTH TELESCOPE
Primary mirror: 8.1-meter single-blank mirror, 8 inches thick and 22 tons; **Location:** Mauna Kea, Hawaii (13,800 feet); **Public:** Seven-nation consortium: United States, United Kingdom, Canada, Australia, Argentina, Brazil, and Chile; **Cost:** About $92 million to design and build; **Start of science operations:** 1999; **Wavelengths:** Optical and near-infrared

WITH AN OPEN-AIR DOME and other innovations, the Gemini North Telescope has pushed the technological envelope. In November it was officially renamed the Frederick C. Gillett Gemini Telescope. GEMINI OBSERVATORY



THE TWO SCOPES combine to give astronomers access to Earth's entire celestial sphere.



GEMINI SOUTH TELESCOPE
Primary mirror: 8.1-meter single-blank mirror, 8 inches thick and 22 tons; **Location:** Cerro Pachon, Chile (9,000 feet); **Public:** Seven-nation consortium: United States, United Kingdom, Canada, Australia, Argentina, Brazil, and Chile; **Cost:** About $92 million to design and build; **Start of science operations:** 2002; **Wavelengths:** Optical and near-infrared

LIKE ITS IDENTICAL TWIN on Hawaii's Mauna Kea, the Gemini South Telescope atop Cerro Pachon in Chile can be completely controlled from a sea-level operation base. GEMINI OBSERVATORY

other than a black hole is possible," says Reinhard Genzel, director of the Max-Planck Institute for Extraterrestrial Physics in Garching, Germany. By all indications the black hole is massive, with roughly three million times the mass of the Sun. Genzel and his team spied a star, called S2, as it passed within just 17 light-hours of the black hole, zipping along at 5,000 kilometers per second, or 11 million miles an hour. S2 orbits the Milky Way's center every 15 years at just three times the Sun-Pluto distance.

Celestial twins: Gemini North and Gemini South

Unlike the Kecks, the 8.1-meter Gemini North and Gemini South duo are identical twins. "Of course, at Gemini South, some of the signs are in Spanish," quips Gemini Observatory director Matt Mountain. The Gemini Observatory project combines the efforts of the United States, United Kingdom, Canada, Chile, Australia, Argentina, and Brazil.

Sited on Mauna Kea, 2,000 feet (600 meters) southeast of the Keck domes, Gemini North is a fully optimized and integrated observatory, meaning that all of the systems were given equal consideration at the drawing board. And since brainstorming began in 1990, the observatory has been a model for how to build the 30- to 50-meter telescopes on the horizon. (See "Big plans," page 43.)

"This is all part of a new approach to telescope building, where we think through everything, from the enclosure to the telescope mount to the adaptive optics and the instrumentation — all as a single system," says Mountain.

The observatory goes to great lengths to control the environment of the enclosures, allowing no more than one kilowatt of the 700 kilowatts of power it takes to operate the Gemini scopes to remain inside. Each 380-ton scope — so precisely balanced that one person can move it — stands on a 20-meter concrete pier high above the turbulent layer of air near the ground. The 22-ton mirrors, cast from ultra-low-expansion glass, are supported by 120 computer-controlled actuators.

Gemini is also becoming a cyber observatory. Each of the Gemini scopes can be completely controlled from sea-level operation bases in Hilo, Hawaii, and La Serena, Chile. Extensive networking and video conferencing have made it possible for numerous programs to be broadcast from control rooms.

"We're making it possible for a guy or gal in Poughkeepsie to sit in their home office with an audio and visual window open to the control room in Hilo or La Serena and participate as if they were in the control room all along," says Jim Kennedy, associate director for operations.

Meanwhile, University of Arizona astronomer Laird Close knows the power of Gemini firsthand. He recently used Gemini North and the Hokupa'a adaptive optics system (which has since been replaced by a new, better system named Altair) to obtain images twice as sharp as those from the Hubble Space Telescope. These revealed a brown dwarf just three times the Earth-Sun distance from its companion star. Prior to Close's work, the smallest known separation between a brown dwarf and its companion was five times greater.

"At the time," says Close, "Gemini was the only observatory in the world where you could use adaptive optics on such faint stars." The Hokupa'a system could count single photons of light, which made it extremely useful for detecting dim, low-mass objects.

Gemini technicians are also working on the next generation of adaptive optics systems that will create real-time, three-dimensional pictures of atmospheric turbulence over the telescopes to give corrections across the entire field of view. In addition, Gemini could become the first fully automated giant observatory.

"One day, our telescope operators will be like the captain of a 747 with his or her arms folded and flying on autopilot," says Kennedy. ◼

To learn about more issues related to the world's largest telescopes, visit http://www.astronomy.com/toc

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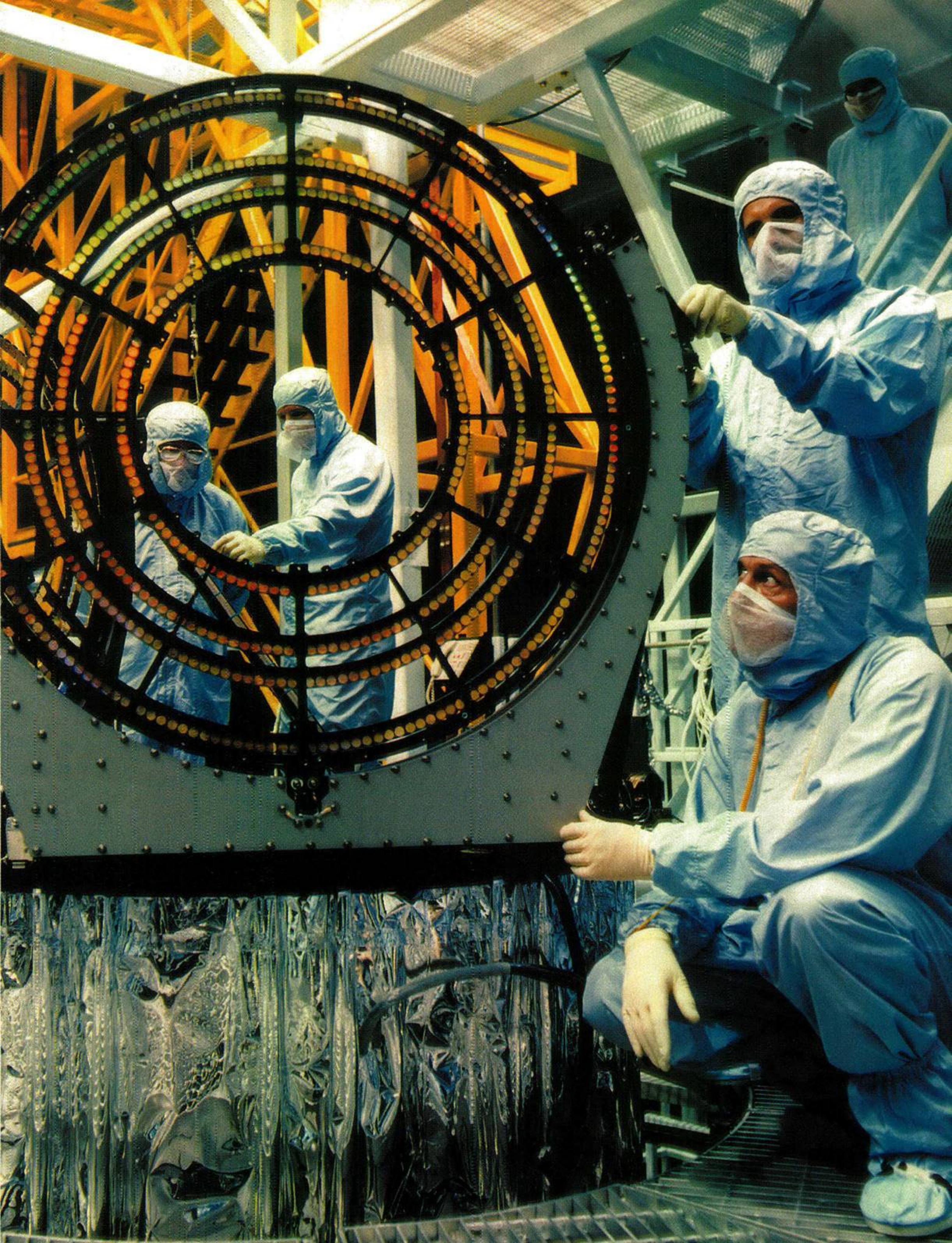
BIG science

"Big science" is moving into astronomy, bringing large experimental teams, multi-year research projects, and big budgets. If this is the wave of the future, why are some astronomers bucking the trend? /// BY STEVE NADIS

Not long ago, four experiments were underway in Geneva, Switzerland, at CERN, one of the world's premier high-energy physics facilities. Each group consisted of 100 or more scientists trying to make the same measurement in slightly different ways, according to Philip Anderson, a Nobel prize-winning physicist based at Princeton. ☾ "When groups get to the 100-plus person level," he says, "it can be deadening from a sociological point of view. I personally would never join such collaborations and find the whole idea quite depressing." ☾ While physicists are trying to nail down the last few parameters of the Standard Model, refining numbers to the 10th decimal point, astronomy is at a different stage, Anderson says. "Every time we build a new machine like the Hubble Space Telescope, we're bound to find something exciting." Yet as astronomy becomes more international and moves toward ever-larger research collaborations, the high-energy physics experience — "Big Science" personified — offers a cautionary tale.

MONOLITHIC PROJECTS such as the orbiting Chandra X-Ray Observatory, in construction at right, are the trend in astronomy. Such undertakings often yield rich results, but at what price to individual creativity? TRW



The biggest projects in astronomy today, such as the Chandra X-Ray Observatory Project and Sloan Digital Sky Survey, have about 100 astronomers on their science teams, with hundreds of others making use of the facility or its data. The core team for the upcoming European space mission Planck already has a few hundred researchers. Some observers wonder how an individual can make a mark in a paper with 100 authors.

"These big, multi-author papers have no identifiable tone," says Margaret Geller, an astrophysicist based at the Smithsonian Astrophysical Observatory (SAO) in Cambridge, Massachusetts. "If a paper has 100 authors, how can it have a personality? I think it's sad, because it reinforces the idea that science is cold and impersonal." Astronomy, she fears, is becoming "a nameless, faceless enterprise like the Human Genome Project."

A related concern is that young researchers — graduate students and post-docs — will have a hard time establishing a career if their contributions are buried within the mass of work produced by a large group. "There's certainly a risk that young people will be exploited, and their work submerged, as they are unlikely to be the top two or three authors on a paper," says University of Wisconsin astronomer Jay Gallagher. But there might be ways around that, he adds, such as rotating the names of lead authors on papers to share the credit.

As research teams expand, the practice of astronomy itself is changing. "It's no longer the lonely astronomer on the mountaintop," says Gallagher. "Now it's an entire group going there, sometimes more than a dozen people on a single telescope."

This pattern is also reflected in publications. "A couple of decades ago, papers with three or more authors were rare; now papers with fewer than three authors are rare," Gallagher notes. The statistics bear him out. From 1975 to 1996, the mean number of authors on papers in the main astrophysics journals increased from two to four, according to SAO astronomer Michael Kurtz, a creator of the Astrophysics Data System, a digital library of scientific papers.

"It looks like the trend toward bigger is here to stay, so the field now has to learn how to deal with it," says Gallagher. "One of the biggest challenges will be learning to share the rewards because, unlike in industry, it's hard to share a profit in academia."

Large groups are a "mixed blessing," adds University of Colorado astronomer Ellen Zweibel. On the one hand, "some people have gotten lost in big projects, assigned unglamorous jobs like writing software." On the other hand, she says, there are potential advantages for a young researcher. "You have a whole team of people automatically interested in your results."

Her Colorado colleague Jim Green concedes that an unlucky graduate student or post-doc could get stuck on a slow-moving project that yields little scientific return for years. But on balance, says Green, the successes of big efforts — such as space missions — outnumber the failures. "These big missions produce so much data, they enable more science than they hinder."

Green develops scientific instrumentation for missions like the Hubble Space Telescope (HST) and the Far Ultraviolet Spectroscopic Explorer (FUSE) — areas where direct participation by graduate students is limited, in part because hundreds of millions of dollars are at stake. "The good thing is that there are a lot of small, inexpensive missions with small instruments that my students can take the lead role in," he says. The trick is in striking the right balance between big and small science. As an active collaborator in HST, which is about as "big" as it gets in astronomy, Green looks out for his students and doesn't drag them into projects that offer little opportunity or responsibility.

When groups get to the 100-plus person level, it can be deadening from a sociological point of view. —NOBEL PRIZE-WINNER PHILIP ANDERSON

While astronomy as a whole is gradually moving toward bigger groups — a shift that might cramp the style of the more free-spirited types — that doesn't mean the field is going down the tubes. With the deluge of data now available, our understanding of the cosmos is steadily advancing on a wide range of fronts. In addition, says Green, "the hiring situation in astronomy is the best I've seen in 15 years."

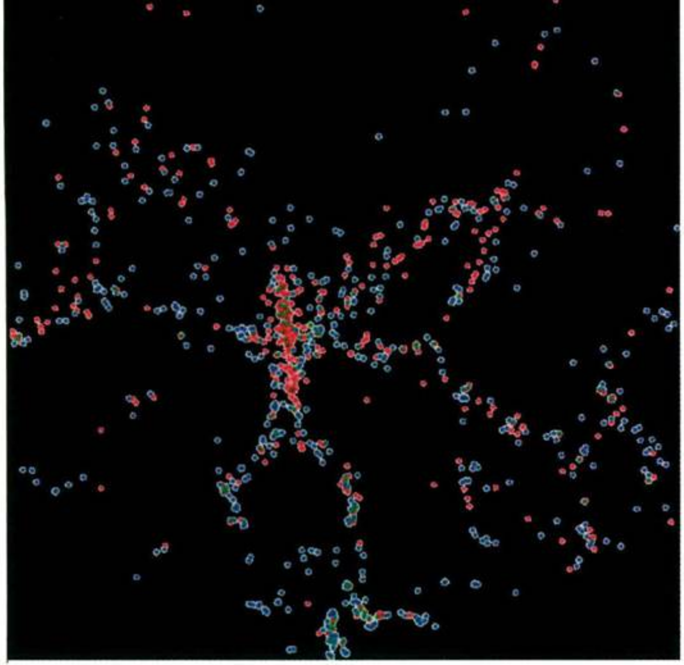
Looking ahead, it's clear that big-ticket ventures are here to stay. But for the health of the field, solo practitioners should have opportunities for creative work outside of mammoth collaborations if they so choose. That will help draw the best people to astronomy, regardless of temperament or working style, while contributing to more diversified research. The following reports come from both sides of the Big Science/Small Science divide.

AN INDEPENDENT VOICE

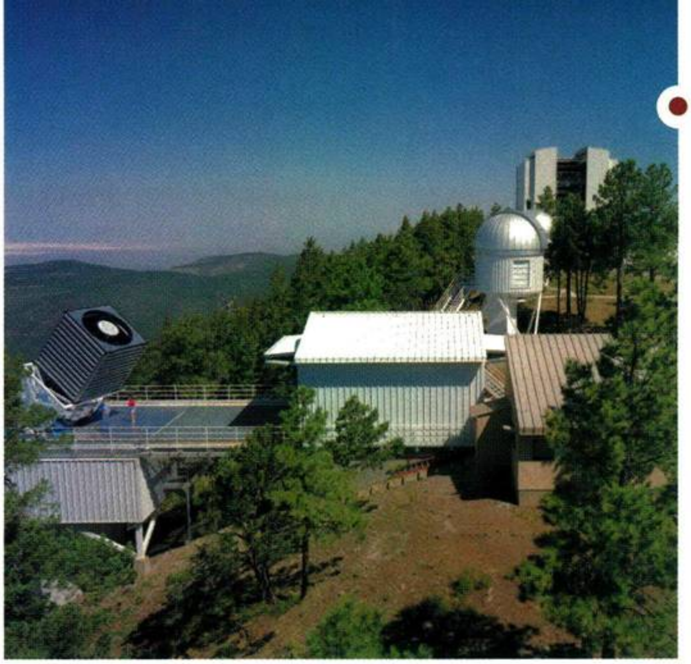
Some astronomers move freely between small and large research groups, but Margaret Geller has never been part of a big collaboration and probably never will be. "I just don't want to work that way," says Geller, who's been based at the Smithsonian Astrophysical Observatory (SAO) for the past quarter-century. Large groups can stifle creativity, she says, and often allow no room for independent-minded mavericks like herself. "The people who make the biggest leaps in science are not doing drudge work in these big projects. Committees don't have ideas; individuals do. Although large-scale efforts like Sloan can make important contributions, it would be sad if they push everything else aside."

Fortunately, Geller has not yet been pushed aside. Her efforts to map the cosmos have shown that the universe has a structure like soap bubbles or foam, with galaxies spread along the bubble surfaces, separated by voids in between. In recognition of this work, she was elected to the National Academy of Sciences and also received a coveted MacArthur Fellowship. She is gearing up for a new galaxy redshift survey designed to fill the niche between the far-reaching DEEP Survey at Keck

Steve Nadis *is a contributing editor of* Astronomy *and a freelance science writer in Cambridge, Massachusetts.*



THE STICKMAN in this map of galaxies in a slice of the sky put a human face (and torso) on our notions of the structure of the universe. Although the human figure itself is something of a fluke, the map does illustrate that galaxies are not scattered uniformly through space as once thought. The team that produced this groundbreaking image in 1986 consisted of three people: graduate student Valerie de Lapparent, and astronomers Margaret Geller and John Huchra. V. DE LAPPARENT, M. GELLER, AND J. HUCHRA



THE MAMMOTH SLOAN DIGITAL SKY SURVEY will also map galactic distribution, but its scope is much larger, eventually covering a quarter of the night sky and a million galaxies — a volume 100 times larger than any other survey to date. The 2.5-meter survey telescope is on the left in this image of Apache Point Observatory in New Mexico. It is housed in the building at center, which was designed to roll away from it during use so that the air above the telescope is as calm and cold as possible. FERMILAB VISUAL MEDIA SERVICES

Observatory and the more "local" surveys conducted by the 2dF Galaxy Redshift Survey and Sloan teams. The SAO survey, which is scheduled to begin in late 2003 at the Multiple Mirror Telescope in Arizona, will be a much smaller collaboration than the Keck, 2dF, and Sloan efforts, which is, of course, the way Geller likes it.

"For me, the trick of staying independent has a lot to do with my age," she says, meaning that as someone in her mid-50s, she entered the field before super-large teams were in vogue. But her qualms go beyond a matter of personal preference. She feels the trend toward bigger, more expensive facilities and teams is dangerous because it can deter young people from entering and staying in the field. Graduate students and post-docs are leaving astronomy because they feel "used," sometimes spending years writing software and doing little in the way of science. "Although we can't compete with industry, which offers top astronomy Ph.D.s $150,000 or more per year, we can offer interesting work and independence," Geller says. "But if you're not going to have this independence and the work is boring, why take a big cut in salary?"

"Some argue that giant data-collecting projects are the way of the future," she notes. "In twenty years, they say, all astronomy will be done by automated machines. But that leaves out the crucial thing — ideas, which are not contained in a database."

COSMOLOGY'S LONE WOLF

Princeton cosmologist Jim Peebles is, by his own admission, something of an anachronism. "Astronomers are moving toward bigger collaborations, but my style, which may be out of date, is to work alone," he says. He's a self-professed loner in an increasingly sociable field, partly by circumstance and partly by disposition.

"When I started working in cosmology in the early 1960s, the field was a lot smaller than it is today, and I didn't have many people to collaborate with," he says. "Plus I have a natural inclination to sit alone and scribble on pieces of paper. Is that style still possible? I think so, because I still do it. But it certainly is not required. Nor is it necessary to work in large groups."

For him, at least, the solitary approach has worked out just fine. The eminent theorist was one of the first to predict that microwave radiation would be a detectable vestige of the Big Bang, and he also predicted that it should bear the imprint of tiny fluctuations from which galaxies, clusters, and superclusters have grown. Much of his work has focused on the evolution of structure in the universe, starting from the nearly uniform conditions that prevailed following the Big Bang.

In the course of a 40-year career, Peebles moved from the study of gravity to astronomy to cosmology. "Maybe I stuck with cosmology because it is possible to be a loner in this field," he says. But the field has changed a lot over the decades. "Sometimes I'm taken aback by the sheer numbers of people working on similar problems these days," Peebles says. "If I were entering science today, I might go into another area where that isn't the case."

Indeed, when he started out in cosmology, many of the fundamental questions were wide open to investigation. It was easier to pick a problem that nobody else was thinking about. Over the years, as data has rolled in from all quarters, the field has evolved, and the outstanding questions have grown more complex. "Some of them can be addressed better by a team of experts, pooling their efforts, but there's still room for the solo operator," he says.

On occasion, Peebles strays from the lonely path and enters a collaboration. For example, he's now part of a Space

/// BIG THINKERS

MASSIMO RAMELLA

ROBERT P. MATTHEWS

NASA

CXC/K. KOWAL

MARGARET GELLER, an astronomer at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, studies the structure of the universe on large scales. Her pioneering work mapping the distribution of galaxies earned her a MacArthur Fellowship and helped spawn a slew of similar surveys. But Geller has shunned large research groups. "In twenty years, [some] say, all astronomy will be done by automated machines," she says. "But that leaves out the crucial thing — ideas — which are not contained in a database."

JIM PEEBLES, a physicist at Princeton University, literally wrote the book on physical cosmology. One of the first to predict that the afterglow of the Big Bang should be visible as microwaves today, he studies the evolution of structure in the universe and shies away from large collaborations. "Sometimes I'm taken aback by the sheer numbers of people working on similar problems these days," he says. "If I were entering science today, I might go into another area where that isn't the case."

JOHN MATHER stumbled into big science right after graduate school when he helped develop a spacecraft to study the remnant radiation from the Big Bang. The results of that project, the Cosmic Microwave Background Explorer (COBE), showed subtle temperature differences in the radiation that proved the early universe was not completely uniform — smoking-gun evidence that structures such as stars and galaxies started out simply as slight overdensities of matter and energy. Now Mather is the lead scientist for Hubble's successor, the James Webb Space Telescope. "Clearly, the United States could afford to build [JWST] on its own," he says. "The reason we don't is that an international community of astronomers also wants to use it and help with the building."

HARVEY TANANBAUM coordinates use of the phenomenally successful Chandra X-Ray Observatory, launched into orbit in 1999. Thousands of people worked on the billion-dollar project, which continually sends back beautiful and scientifically interesting images. "I entered x-ray astronomy in the late 1960s when it was a brand-new field because it offered the chance to study the most energetic phenomena in the universe," he says. "If the science weren't so exciting, it wouldn't be worth all the headaches of running a project this big."

Interferometry Mission team, planning to study the proper motions of nearby galaxies — a capability that was inconceivable until recently. "Talk to me in a couple of years, and I'll let you know what I've learned about Big Science," he says.

BIG IDEAS BEGET BIG SCIENCE

John Mather never set out to become one of the major players in big-time astronomy. But things worked out that way, explains the Goddard Space Flight Center scientist, mainly because "my first idea happened to be a good one." After getting a Ph.D. from Berkeley in astronomy in 1974, Mather was eager to follow up on his thesis work, which involved measurements of the cosmic microwave background from balloons and the ground. "I realized a space project was the way to go," he recalls. Soon he joined forces with Reiner Weiss, Mike Hauser, and Dave Wilkinson, who formed the nucleus of the Cosmic Microwave Background Explorer (COBE) project. The satellite was launched in 1989 and collected data for four years, in the process transforming cosmology into a quantitative science. "That was a 20-year effort on my part," says Mather. "It turned out to be worthwhile, but you never know when you start something like this."

At about the time COBE was put into orbit, Mather was asked to lead a team to develop a successor to the Hubble Space Telescope. The result, the billion-dollar James Webb Space Telescope (JWST), is scheduled for launch in 2008. "It will be a unique observatory for the foreseeable future, and thousands of scientists all over the world will want to use it," says Mather.

He stresses that he is not drawn to projects because of their size. If anything, it's the other way around: Projects become big, and attract large numbers of users, if the original idea is good enough and the facility can support novel observations. "Most astronomy is still done in small groups, but sometimes it makes scientific sense to pull together," he says. "Clearly, the United States could afford to build [JWST] on its own. The reason we don't is that an international community of astronomers — from Europe, Japan, Canada, and elsewhere — also wants to use it and help with the building."

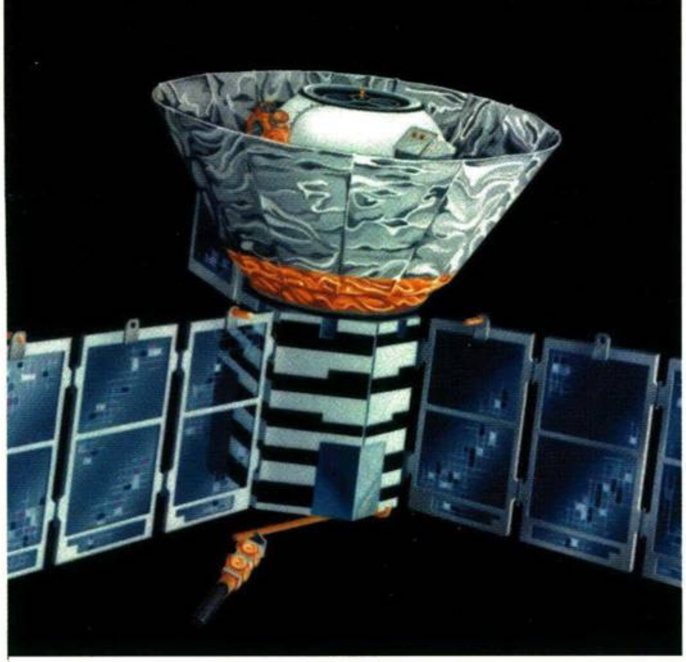
Mather acknowledges that bigger is not necessarily better. "Many astronomers are thrilled to do something smarter, rather than bigger," he adds, by using technologies like adaptive optics, for instance, which drastically improve images by correcting for atmospheric turbulence.

Still, given Mather's track record — from graduate school to COBE to JWST — his next endeavor is likely to be big, as well. In fact, he's already involved in planning JWST's successor — a cold telescope that could explore longer wavelengths in the far infrared. "I'll probably have a role in this project, but I might decide to go back to writing scientific papers instead of running it," he says. "I'd like to think I could still do that."

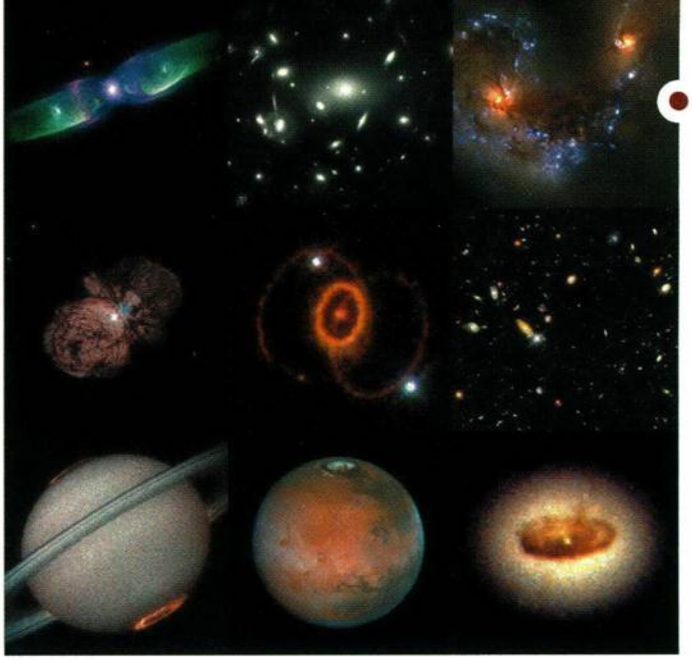
X-RAY VISION

As director of the Chandra X-Ray Observatory Center, based at the Smithsonian Astrophysical Observatory, Harvey Tananbaum is one of the most influential people in x-ray astronomy. He coordinates use of the premier instrument in the field's history, with about 1,000 scientists worldwide using Chandra either to make observations or to analyze the mountains of data it has amassed. Generally speaking, Tananbaum enjoys the responsibility, except perhaps when he gets beeped at 4 A.M. by astronomers hoping to amend the schedule in order to follow up on a gamma-ray burst or other noteworthy event.

Chandra's launch in 1999 was incredibly gratifying to Tananbaum, who co-authored the first proposal for the observatory in 1976 with Riccardo Giacconi, co-recipient of the 2002 Nobel Prize in physics. "With a space mission, there's always the prospect it could fail," Tananbaum says. "But once you have something up there and working, it's a great feeling."



THE COSMIC MICROWAVE BACKGROUND EXPLORER (COBE) satellite, launched in 1989, cost a few hundred million dollars and involved about 1,500 people. In 1990, it measured the temperature of the cosmic microwave background radiation to be 2.7° Celsius above absolute zero. That same year, three scientists at the University of British Columbia sent up a rocket-borne experiment named COBRA that measured the same thing for about a million dollars. NASA



THE HUBBLE SPACE TELESCOPE has produced some of astronomy's most breathtaking images — and insights — since its launch in 1990. Top row: Twin Jet Nebula around dying star M2–9; galaxy cluster Abell 2218; colliding Antennae galaxies. Middle row: massive star Eta Carinae; rings around Supernova 1987a; galaxies in the Hubble Deep Field. Bottom row: Saturn with aurorae; Mars; a cloud of gas and dust around the supermassive black hole at the center of NGC 4261. STScI

Building the spacecraft took hundreds of scientists, thousands of people, and billions of dollars. The scale is not so different from large physics collaborations at CERN and Fermilab, he says. "But I wasn't drawn to the project because it's big and cost a lot of money. I entered x-ray astronomy in the late 1960s when it was a brand-new field because it offered the chance to study the most energetic phenomena in the universe." He soon participated in the Uhuru x-ray satellite mission, which was launched in 1971, and in the Einstein Observatory mission, launched in 1978. He helped discover the first x-ray binary and published roughly 100 papers between 1970 and 1985.

His publication rate has dropped off sharply in the last 15 years, while he's focused mainly on getting Chandra into space and operating smoothly. He's also chair of the science team planning Constellation, another big x-ray mission. At present, Tananbaum has no plans to resume his career as a research scientist. "I'm proud of what the satellite is doing, and can take a bit of ownership in a great result, even though it's not my own research," he says. "If the science weren't so exciting, it wouldn't be worth all the headaches of running a project this big."

SOUNDING OUT SPACE RESEARCH

In 1990, COBE and "an unnamed rocket-borne experiment," to quote a recent *Science* article, determined that the cosmic microwave background, a remnant of the Big Bang, had a temperature of 2.7° Celsius above absolute zero. But the unnamed experiment actually had a name. Called COBRA, this million-dollar effort mounted by just three people at the University of British Columbia made the same finding, albeit two months later, that COBE did. (In comparison, COBE cost about $400 million in today's dollars and involved about 1,500 people.)

COBRA took data for only eight minutes on its short arc into space, but in that time, it measured the microwave background temperature "equally well" as the more elaborate COBE, says Peebles. Among other things, the experiment demonstrated the potential of sounding rockets as a cheap way to make astronomical observations in space.

"One lesson from COBRA is that a small, dedicated group can have an impact, especially if they know how to build a very specific piece of equipment," says British Columbia astronomer Mark Halpern, who participated in the 1990 experiment. "You can definitely do a lot with just a few people, but you do it slowly. It took us eight years to build the rocket, whereas a bigger group might have done it in a few years."

Through NASA's Sounding Rocket Program, which supports about 50 different projects across the country, graduate students and faculty researchers can get hands-on participation in space science at a modest cost. For example, University of Colorado astronomer Jim Green and his colleagues built the spectrograph for the Far Ultraviolet Spectroscopic Explorer (FUSE), launched by NASA in 1999. But the satellite's technology was first tested on a sounding rocket in 1994 — a thesis project carried out by then graduate student Scott Sarlin.

"That $1 million effort gave NASA the confidence to go ahead with its $100 million mission," says Green. Another of his graduate students, Matthew Beasley, is developing a new spectrograph for FUSE's proposed successor, which was tested in a sounding rocket flight in November 2002. As Green says, "We can do good science on these small missions, making observations that have never been done before."

Find out what graduate students think of their experiences in "big science" by visiting http://www.astronomy.com/toc

Catch a celestial tango

In sometimes-crowded deep space, small galaxies dance, merge, and grow. /// BY PAMELA L. GAY

The universe once was dominated by small structures — the precursors to dwarf galaxies and infant star clusters — that nestled quietly within halos of dark matter. These primordial galaxy seeds did not stay isolated for long, however, and over the aeons they have violently encountered others of their kind. Through hierarchical clustering, small structures have come together to build progressively larger and larger systems of stars, dust, and gas.

This clumping of matter continues today, as our own Milky Way Galaxy hungrily consumes the Sagittarius dwarf galaxy. Our home galaxy will slowly devour other dwarf galaxies — Fornax, Draco, and Ursa Minor — and even the Large and Small Magellanic clouds. Eventually, we too will be absorbed into a larger system, as Andromeda and the Milky Way dance a deadly tango of destruction and reformation.

Our sky is littered with the wreckage of galaxies in collision. In their early stages, merging galaxies may not stand out too strangely from their isolated peers. M51, the Whirlpool Galaxy, is merging with NGC 5195. A solitary tail of material currently bridges these two systems, prophesying their eventual coalescence. Many astronomers think the "grand design" spiral arms in M51 are transitory structures promoted by NGC 5195. Similar grand design spirals, such as M101 and NGC 1232, also have companion systems. Spiral rings around galactic nuclei and galactic bars also may be driven by galaxy-galaxy interactions.

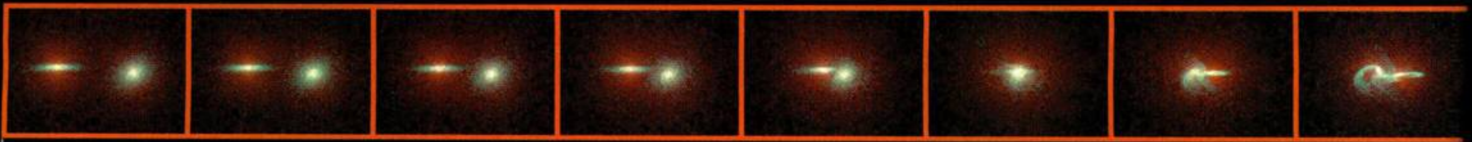
As mergers progress, orbiting in tighter spirals and sweeping past one another, strange structures can appear. Tidal tails form, and dust and gas are driven into the galactic cores where star formation is triggered. Mergers may fuel the active central black holes in Seyfert galaxies and quasars. Fireworks in starburst galaxies are also often set off by merger activity.

Over time, once well-defined disks will be disrupted, leaving behind irregular structures that are determined by the systems' initial masses, orientations, and velocities. Double nuclei with twin supermassive black holes beam high-energy photons to x-ray observers and may, at the moment of joining, flash gamma-rays and send gravitational waves careening through space.

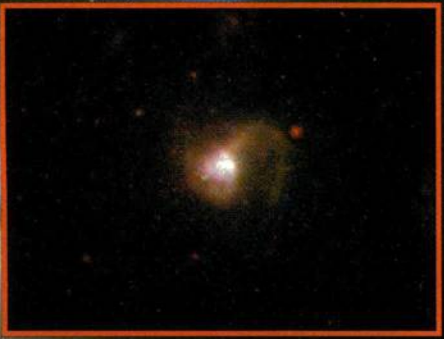
Each collision results in its own strange carnage. More gentle mergers may form an otherwise normal-looking disk that is simply warped, while side impact collisions can lead to bizarre polar rings. Galaxies, like people, do not like to be alone. They form pairs and groups, as well as clusters that congregate into superclusters that trace out the superstructure of the cosmos. Within each of these systems, some galaxies will simply get too close and create explosive pictures of nature at its most violent. ■

Pamela L. Gay spent four years getting personal with cluster galaxies.

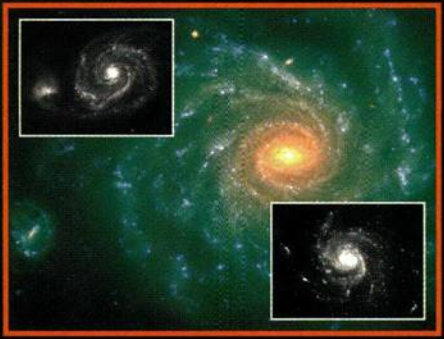
Peruse an exhibit of peculiar galaxies and see how "The Mice" may have formed by visiting http://www.astronomy.com/toc



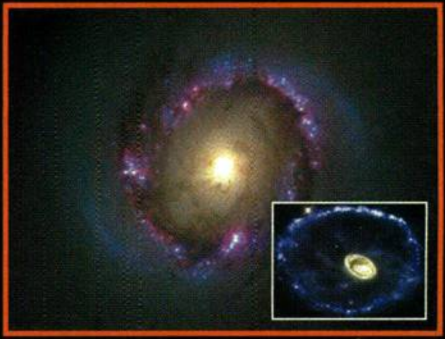
OVER 400 MILLION YEARS, two identical disk galaxies come together and form a disrupted system resembling "The Mice." HIBBARD AND BARNES, HST



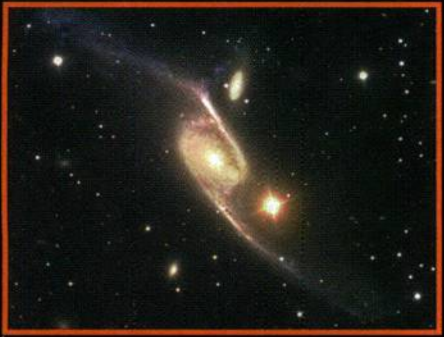
SMALL, IRREGULAR COLLECTIONS OF STARS, dust, and gas form the building blocks of young galaxies. Giant galaxies form from youthful dwarf systems, such as POX 186 (shown here). NASA AND MICHAEL CORBIN (CSC / STScI)



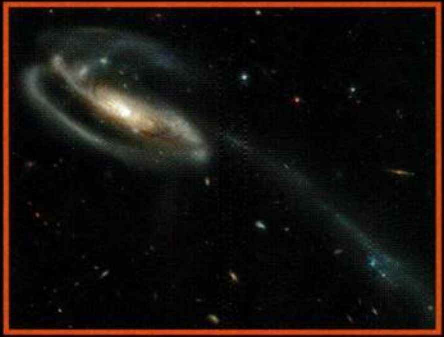
GRAND DESIGN SPIRAL GALAXIES , like these, owe their structure to interactions with companions. Main image: NGC 1232 with NGC 1300. Top left: M51 with NGC 5195. Bottom right: M101 (companion not shown). M51, M101: P. L. GAY / ASA (UT). NGC 1232: ESO



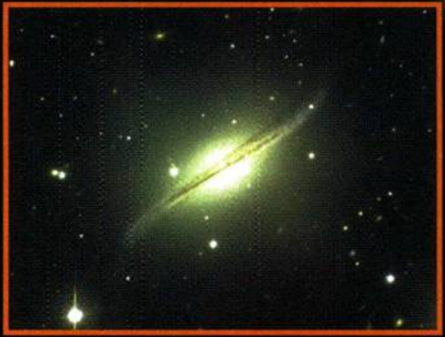
STRANGE RINGS OF STAR FORMATION may be driven by close encounters of the galactic kind in the Cartwheel Galaxy (main image) and in NGC 4314 (inset). NGC 4314's ring is just 5 million years old. NGC4314: G. F. BENEDICT ET AL. / NASA. CARTWHEEL: KIRK BORNE (STScI) / NASA



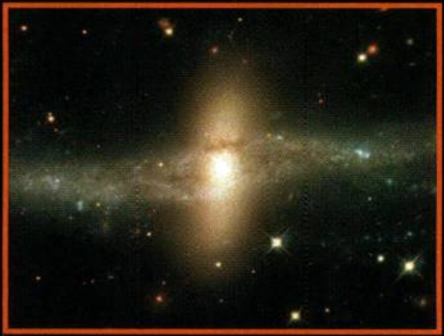
BARRED BY ANOTHER, NGC 6872 is structurally warped by interactions with IC 4970 that may be driving the bar in its bulge. If you look carefully, you can see a small bridge of material linking these systems. ESO



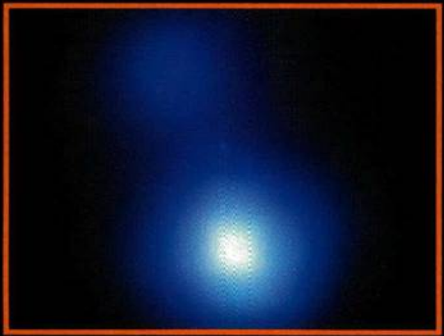
TIDAL TAILS FORM as one galaxy passes another, sweeping out material and distorting spiral arms. One of the sky's most dramatic examples is the Tadpole Galaxy. The culprit behind this structure is a small system hiding in the tidal stream. ESO



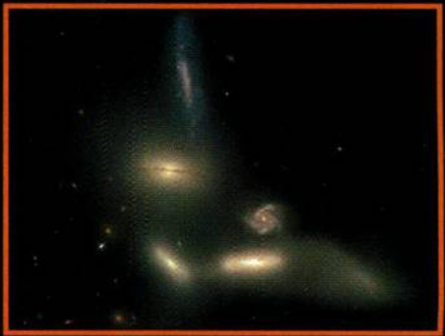
WARPED BY ITS INTERACTIONS, ESO 510-13 recently swallowed a passing companion. The disk's warp is caused by dust that hasn't dynamically settled into its new parent system. It will slowly flatten out and hide its past. ESO



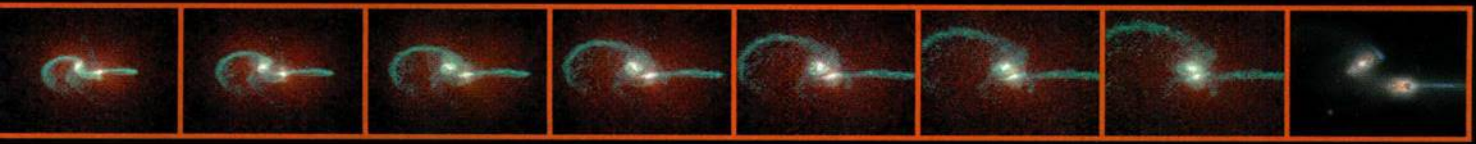
WRAPPED AROUND THE WRONG AXIS, this disk of material is the dramatic result of a side impact collision between similar spiral galaxies. Colliding at right angles produced perpendicular disks. HUBBLE HERITAGE TEAM (AURA / STScI / NASA)



DOUBLE NUCLEI HAUNT THE MERGING CORES of coalescing galaxies. Over time, twin black holes, such as these in NGC 624C, will merge into a single dark object. We will detect this moment from its gravity waves. NASA / CXC / MPE / S. KOMOSSA ET AL.



BECOMING ONE, this group of four merges in Seyfert's Sextet. The small spiral is a background galaxy, and the blob of light in the lower right is material stripped out of the merging systems and is not a galaxy. NASA, J. ENGLISH ET AL.



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Have minorities broken astronomy's glass ceiling?

At last year's American Astronomical Society meeting in Washington, D.C., Dave Eicher, editor of *Astronomy*, and Rich Talcott, senior editor, met with a group of astronomers to discuss the state of the AAS Minorities Committee. An edited transcript of the discussion follows. The full-length version of the conversation can be found on our website, http://www.astronomy.com.

Eicher: Welcome, everyone. Let's start by asking everyone to introduce him or herself and talk a little bit about what you do. Please describe what you are now doing with the Committee on the Status of Minorities in Astronomy (CSMA) and what the committee's goals are.

Stassun: I'm Keivan Stassun, a postdoc at the University of Wisconsin-Madison, and a Hubble Fellow. My research is on star formation. For the most part we're trying to launch the committee with a number of efforts. Phase One is to enhance the visibility and awareness of the committee. We're hoping that over the next year or so we'll get more of the AAS community contributing to our newsletter, *Spectrum*.

Urry: I'm Meg Urry. I'm a professor of physics at Yale University and director of the Yale Center of Astronomy and Astrophysics. My expertise is in active galaxies, which are powered by supermassive black holes. I also chair the American Astronomical Society Committee on the Status of Women in Astronomy. We try to include in our newsletter, *Status*, information about the difficulties for women in astronomy. Our activities include sponsoring sessions at AAS meetings, putting out a weekly e-mail, and so on. We're looking forward to helping the Minorities Committee leverage on whatever we've been able to do.

Knezek: I'm Patricia Knezek, the WIYN (University of Wisconsin, Indiana University, Yale University, and the National Optical Astronomy Observatories) Instrumentation Project Manager and am presently employed by NOAO. I work primarily on low-surface-brightness galaxies and dwarf galaxies. I am also the co-editor, with Meg Urry, of the AAS women's electronic weekly newsletter. I'm interested in putting this into a lower education level because I am involved in K-12 outreach.

Koerner: I'm David Koerner, an astronomer at the University of Pennsylvania, and I have been involved with gay and lesbian astronomy issues for a while. I work on the formation of planetary systems, doing observations of circumstellar disks.

I'm very excited that the minorities committee will become more active, and also that now they seem open to letting us in under the umbrella of a minority.

Eicher: We have three partly overlapping groups. I wonder if you could each talk about each of the three groups and where you see their missions and where you see things in the future?

Urry: The situation for women is a little different than the situation for minorities and probably even farther apart from the situation for gays and lesbians. The number of women in astronomy has been growing. A quarter of all the Ph.D.s and a quarter of the grad students are women.

The attrition of women, though, is still higher than that of men at every level. Women are not accorded the respect that men are. The expectations for women are lower.

Eicher: There's still extra proving of oneself to do.

Urry: Yes, very much so.

Eicher: The problems are a little more disguised, but still there.

Urry: They're harder to see. So step one ought to be increasing the numbers of minorities, but even if we were fifty-fifty there's still the perception that men are the leaders at every high-level profession.

Stassun: The bean counting is important, but let's not lose sight of the fact that it's an order of magnitude problem. We know from the 2000 U.S. Census numbers that blacks, Hispanics, and Native Americans make up about 25% of the population. And yet they make up about three percent of the permanent astronomy world. That's the chasm that ultimately we hope to bridge.

Perhaps the greatest schism in minority representation is the K-12 problem. It really is difficult getting minority kids involved. I'm trying to focus on those aspects of the problem that seem feasible and understandable. In the short term, I see us identifying strategies that my colleagues feel they can actually do something about. We are trying harder to bring astronomy to minority undergraduate students and their institutions. And, conversely, we can try harder to bring the students to us by taking advantage of our Research Experiences for Undergraduate programs. These programs bring undergraduates in for the summer, connect them with a mentor, and get them involved. When students are involved in those summer research programs they are more likely to go on to graduate school in those institutions.

> Even if we were fifty-fifty there's still the perception that men are the leaders. – MEG URRY

Another major step is debunking the popular myth that if you're a minority with a Ph.D., you are set. It's really important for people to realize that that's not true. In the first issue of *Spectrum*, I included an article with a study that found that among postdocs and faculty members, there was not a single instance of minority scientists who had been called up and recruited strongly. The bottom line was that, despite a lot of talk and mythology, faculty search committees still rely on antiquated methods. It's very much like an old boy's network. Minorities, despite their credentials, are often just not plugged into this network that would [help them be recruited].

Urry: They're invisible.

Stassun: As a committee we're compiling an online directory to make it easier for our colleagues to identify potentially qualified minorities.

Urry: You have a great idea. If you only have one or two Ph.D.s a year for African-Americans, and I suppose it goes up to five or something including Hispanics, you could publish in every issue of *Spectrum* a picture and a bio of the last such person to get a Ph.D.

Stassun: That's a fantastic idea.

* * *

Talcott: How much do you see [minority representation in astronomy] as a problem of the society in general versus astronomy in particular?

Stassun: I think everyone who is involved in minority issues recognizes that the bulk of the problem is society in general.

Eicher: Some of that is uncontrollable.

Urry: In the case of women, twenty years ago the number of girls who were taking appropriate math classes in high school was lower than it is today. My colleagues can have enormous influence over graduate and undergraduate problems. There's a trickle-down effect, too. As more women move further up and succeed at higher levels, young girls see that it's possible for them to succeed also. Having role models is enormously important.

* * *

Koerner: It's startling to hear [you] talk. We have no statistics. Kids identify themselves as this minority much later, but the discrimination starts well in advance.

Eicher: There's an added layer of complexity.

Koerner: The idea that we might have any statistical knowledge to support the magnitude of our problem is impossible. A large number of professionals "come out," so to speak, and identify themselves as gay, often as undergraduates. It can be incredibly traumatic, and I've seen it derail them on into grad school.

Urry: Not only do you not know your statistics because not everybody is out, but how could you document people's attitudes?

Koerner: You're right. Because things are not comfortable, there is no representation. It hurts astronomy. If people feel unrepresented they are less productive and more tentative. I think a lot of gay people see astronomy as a safe haven because the universe doesn't call them names. I can think about the Big Bang or whatever and it doesn't judge me.

Eicher: Sounds like it's a psychologically benign area.

Koerner: Yes, and yet I've heard lots of stories of peer discrimination where students feel there's no recourse with faculty. They're so afraid of discrimination they feel they may jeopardize their career if their status is known.

Urry: It seems to me that you dissipate a lot of your energy maintaining this bubble of invulnerability. That's identical to the situation for women and minorities. All the women I know are spending half their time trying to build themselves back up because they feel abraded by the system.

Koerner: It places a great demand on your individuality, too. One of the first Supreme Court cases over discrimination was about security clearance for a gay man who was an astronomer. He was fired for being gay. So a lot of people were and are most comfortable with complete invisibility. Now officially that's changed.

[Van Dixon joins the conversation.]

[Dr. Dixon studies UV-bright stars in globular clusters. These hot, blue stars are near the ends of their lives and will soon collapse to become white dwarfs. He does most of his work at far-ultraviolet wavelengths, where the stars are brightest.]

Dixon: I'm Van Dixon, and I'm involved with the Gay, Lesbian, Bisexual, Transgender, Queer Astronomers (GLBTQastro) group . I've been involved with organizing dinners at AAS meetings so that like-minded people can

DAVID KOERNER

DAVID KOERNER received his Ph.D. from Caltech in Planetary Science. His interest in the Minorities Committee is to establish gay, lesbian, and bisexual representation that will send a signal to young GLB astronomers, one that will free them from carrying an unjust burden of covered-up identity for the sake of career success.

KEIVAN STASSUN

KEIVAN GUADALUPE STASSUN is currently a postdoctoral researcher in the Astronomy Department at the University of Wisconsin-Madison. He runs a program called "Scopes for Schools," which puts real telescopes in the hands of teachers and minority youth for hands-on science projects.

LAURA MILLER

MEG URRY is Professor of Physics at Yale University. She maintains a long-standing interest in the issue of women and minorities in science. She chairs the Committee on the Status of Women in Astronomy. In March 1992, she led the U.S. delegation to the first International Conference on Women in Physics.

BRAD WHITMORE

PATRICIA KNEZEK views her role on the Committee on the Status of Women in Astronomy as part of her involvement in teaching and outreach. She hopes that, "someday, when a child reads the words 'The scientist found. . .', the picture that forms in the child's brain isn't automatically a white male in a lab coat."

RAVI SANKRIT

VAN DIXON looks to the Minorities Committee to increase awareness in the larger community of the unique concerns for minority astronomers, to let people know that groups like AAS-GLBTQ exist, and to provide a forum for minority astronomers to engage in discussion with the larger community.

meet each other and share their concerns and issues.

Eicher: Since you've been involved, how has the attitude of the AAS changed toward your group?

Dixon: Until quite recently, there was never any mention of us. We've lacked the confidence to even approach the Society and ask for recognition.

Eicher: What you met was resistance.

Dixon: What I met was an explanation of the status quo and the difficulty of recognition, which of course I knew, and not any apparent support for bridging that.

* * *

Knezek: One of the issues facing gay and lesbian astronomers, that I'm seeing, is that they don't know whom to approach.

Dixon: One sort of problem is that when we've had some issue that we wanted to rattle [the council's] cage, most of the people in our group are not in a position to rock the boat. One thing I'm really excited about is that our group, working along with the Minorities Council, now has a platform to approach the larger community with our concerns.

Eicher: Based on that, where do you see your group going in the future?

Dixon: At this point our goals have to be far less ambitious than those of the other minorities. The actual official recognition by the AAS, allowing us to be visible to others in the community, is the main thing.

Koerner: Since Keivan and I started talking last summer about whether or not our group should be under the umbrella of the Minorities Committee, it's become clear that their issues are distinct from ours. So it's a difficult fit. It would still be optimal for us to have our support group grow under the auspices of the Minorities Committee. We know that you, too, have visible mentors for support. I would think that amplifying that part with your own efforts and including us in this would be great. This would not require a lot of time but would have a very strong impact.

Urry: Well, I'm wondering if you want to create a category of people who are "safe," but not necessarily gay, who would like to participate.

Koerner: We had a discussion about that five years ago, and people were concerned because they didn't trust the situation.

Urry: Let's say one of your members is going to interview somewhere. And you had on your friends' list someone at that institution. That would be a very valuable piece of information. Someone they could discuss things openly with. I think it's just getting to that level, where there are enough people who are willing to be friends to make a difference.

* * *

Stassun: I wonder if I can raise something that resonates with the group here. Perhaps it's the strongest point of contact with all three of our groups. In the context of minority issues, I've heard this referred to as "the minority tax." What I mean by that is the fact that in academia, or in professional societies, the folks who care about and work on minority outreach are minorities. That's a self-imposed burden because we're speaking as minorities. On the other hand, it is the tacit assumption by our colleagues that if anyone is going to do the minority outreach, it's going to be the one minority faculty member. People would like to see the issue addressed, but it falls on the very people we're trying so hard to get — and keep — within the profession. Unfortunately, this additional work can come at the price of a successful career.

Eicher: There's something of an irony involved here.

Urry: It's also true that whatever work I do in that arena of minority outreach takes away from research. We do this not because anyone is rewarding us but because we have a sort of passion for justice.

* * *

Eicher: The numbers situation for women astronomers seems vastly better than it was years ago.

Knezek: Yes, but they're still representative. Ten years from now the numbers may not be fifty-fifty, but they'll be more balanced than they are now, we can hope.

Urry: The more we get this message out to the public, the better off we'll be. A few years ago in Atlanta at a session on women in astronomy, someone got up and said, "Why are we talking about going from ten percent to twenty percent?" I thought, any goal short of fifty-fifty is irrational. You have to ask for what's right, not what you think you can get.

Dixon: One of the most insidious things we encounter is someone who says, "Well, things are getting better." Slowly, but surely.

Eicher: In other words, let's not worry about it too much.

[laughter]

Koerner: Right. That's often what we encounter — well-meaning colleagues who don't recognize what really has to be done to improve the situation. "I'm hearing more about it so it seems like it's getting better, so everything's okay."

Stassun: We really need to insist on parity, on equity.

Koerner: It's a fine line to walk. We can't do things that will inflame psychological or sociological ignorance, and yet we can't just assimilate to that either.

Stassun: One message that would be nice to get out is that our slim numbers present an opportunity for leadership. To young people who are considering a career in science, I would say that in astronomy there's a lot of room for women, people of color, and gays and lesbians to have a good career. That's not to say that they'll have a free-and-easy ride, but opportunities will be there.

Talcott: In some ways it may be more important to make those opportunities more visible than the barriers.

> One message that would be nice to get out is that our slim numbers present an opportunity for leadership. – KEIVAN STASSUN

Knezek: Our last two AAS presidents have been women. There are gay and lesbian astronomers doing important research. There are prominent black astronomers, including the director of the Rose Center for Space. These people also serve as role models. We're succeeding on some levels. We'll be fifty-fifty someday.

Urry: There's tension here. You don't want to be too rosy, because then people think everything's fine. You don't want to be too negative because then you turn people off. It's difficult to strike the right balance. When women come to me for advice I cannot actually tell them they won't have any troubles. On the other hand, I'm desperate that there be more women.

Eicher: Will they have more troubles in this field than in other fields of academia?

Urry: Chemistry graduates slightly more Ph.D.s to women than astronomy, but faculty hires in chemistry are quite a bit lower. So astronomy is doing pretty well. In the leadership positions of this society, women are very well represented. The situation compared to biology or medicine or law is much worse, however. And it's changing slowly. So they do have alternatives, and many women are attracted to the cosmic glory of astronomy but are put off by the total impracticality of it. They want to be helpful to others, as in medicine or biology.

Stassun: I also think that it's critical to understand how much of this interest [for women in astronomy] comes up in the early years.

Urry: We could have a great conversation with Janet Mattei, for example, about the role her organization [the American Association of Variable Star Observers] plays in the work of women and minorities. I've never discussed it with her.

Stassun: That's a good point. Amateurs outnumber us. They probably have much stronger connections in some ways. And perhaps a stronger interplay between amateurs and professionals could help more women and minorities get involved.

Eicher: In the amateur community the demographics are overwhelmingly white male. Maybe 15% of the group consists of women. The lack of diversity is striking. How do you get a more diverse group?

Knezek: What I try to do is to participate in star parties. You can't underestimate the role of seeing women or minorities playing a part.

Stassun: Our colleagues in the secondary schools may have the strongest role to play in this.

Urry: The web helps. I've received a dozen or more e-mails from young girls saying, "I'm a high school student; I need to know how to be an astronomer, how did you get there?" and so forth.

Knezek: That helps a great deal, just providing outreach.

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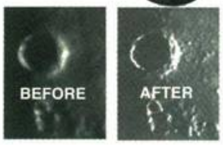

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BY MARTIN RATCLIFFE AND ALISTER LING

MAY 03

The Moon and Earth take center stage, casting their shadows on each other in a pair of spectacular eclipses. Meanwhile, Mars gears up for the apparition of a lifetime.

Get in line— it's eclipse time

When worlds align, wonderful things can happen. Best of all, you can experience most of these wonders from the convenience of your backyard or balcony, and there's no admission charge for the shows. This month, the Sun nearly disappears, the Moon gets bronzed, Mercury's disk slides across the Sun, and Jupiter's moons pull a series of vanishing acts.

A total lunar eclipse on the night of May 15/16 gets top billing in North America. Just after 10 P.M. EDT, Earth's dark shadow begins biting away at the silver-white Full Moon. In a little more than an hour, Luna will be bathed in a fiery copper glow. This is a good time to stretch your sense of color; dozens of shades exist between yellow-orange and coppery-red.

The last total lunar eclipse visible across North America occurred on January 20/21, 2000. The wait for the next one won't be as long: It comes just six months from now, on the evening of November 9.

A sunrise solar eclipse greets western Europeans on the morning of May 31. This alignment at New Moon produces a partial eclipse for much of Earth's Eastern Hemisphere but an annular (ring-shaped) one for Iceland, northern Scotland, and central Greenland. The partial eclipse also reaches over the pole, so observers in Alaska and the Canadian arctic can see it as well.

A COPPER-COLORED MOON hung in a darkened sky during the August 1989 total lunar eclipse. Will the Moon take on a similar color when it slides through Earth's shadow on May 15/16? TERENCE DICKINSON

Mercury passes in front of the Sun on May 7, blotting out a tiny bit of the brilliant light, although it won't be noticeable to the naked eye. Because Mercury appears so much smaller than the Sun in our sky, it simply shows up as a small black disk crossing the face of our star. This phenomenon is called a transit. Although the timing once again favors the Eastern Hemisphere, the transit's last minutes can be seen from the East Coast of North America inland to about Lake Erie.

Jupiter's four bright moons continue their mutual eclipses and occultations. For five out of every six years, they shadow play only with Jupiter, but in this sixth year, they also play with one another.

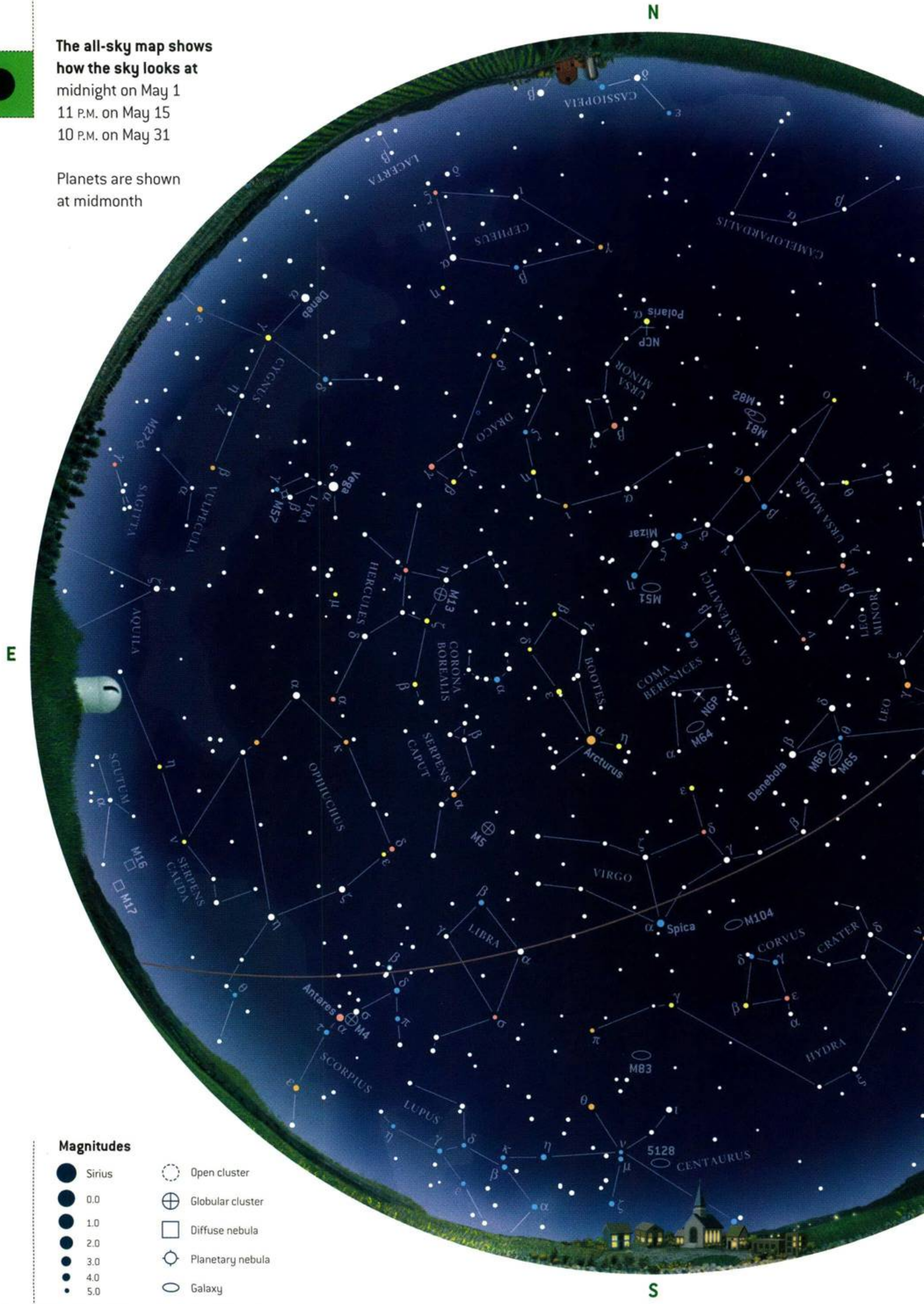
The Moon almost keeps to the same orbital playing surface as the planets. It crosses this plane during the lunar eclipse, stays below it for two weeks, then rises through it again during the solar eclipse. The young crescent Moon pops up into the evening sky on May 2, slides by Saturn on the 4th, and joins Jupiter on the 8th. Sharp-eyed observers can see Jupiter without optical aid that afternoon by using the nearly First Quarter Moon as a guide. Travel eight moonwidths south along the line of the terminator, and Jupiter will appear as a faint dot against the blue sky.

Mars grows bigger and brighter on the way to its best appearance in more than 50,000 years. Stay up past midnight or, better yet, wake up before dawn when Mars has climbed higher. Surface details are becoming visible, and observer experience has shown that, to see them, it's best to train your eye early.

Asteroid Vesta remains an easy target for binoculars. As long as a streetlight doesn't shine in your face, you can find Vesta from the city. In contrast, to see Comet C/2001 RX_{14} (LINEAR), you'll need a dark country sky and an 8-inch scope at the beginning of May.

The all-sky map shows how the sky looks at
midnight on May 1
11 P.M. on May 15
10 P.M. on May 31

Planets are shown at midmonth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Globular cluster
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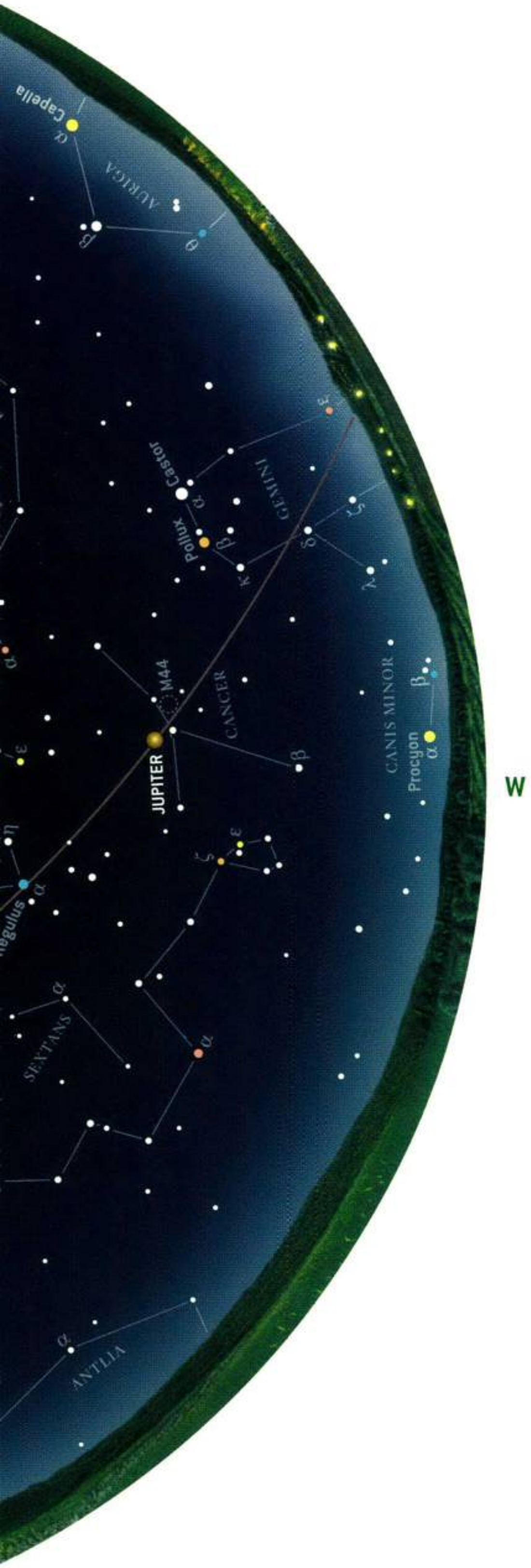
Planetary nebula
Galaxy

This map portrays the sky at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. T
overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.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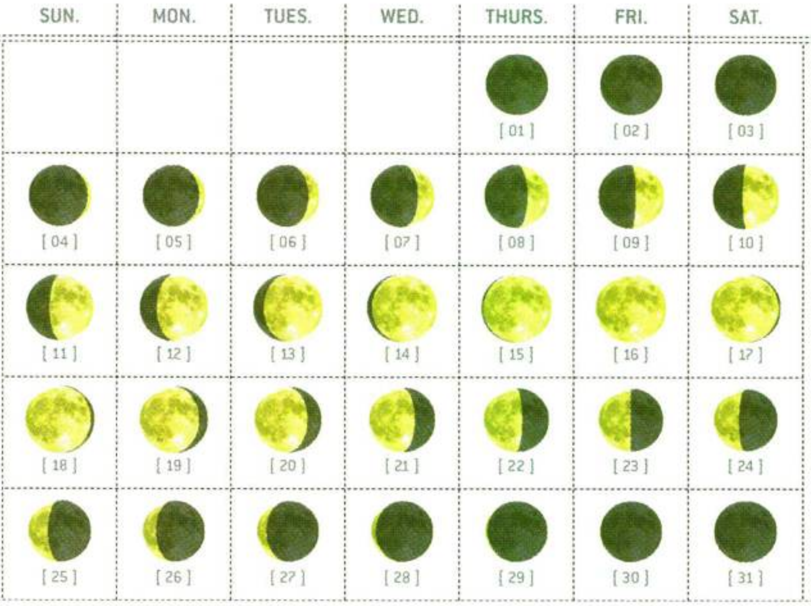

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01 The Moon is at apogee (252,606 miles from Earth), 3:38 A.M. EDT

New Moon is at 8:15 A.M. EDT

05 The Moon passes 3° north of Saturn, 5 A.M. EDT

Eta Aquarid meteor shower peaks

07 Mercury is in inferior conjunction, 3 A.M. EDT; transit

08 The Moon passes 4° north of Jupiter, 2 P.M. EDT

09 First Quarter Moon is at 7:53 A.M. EDT

13 Mars passes 2° south of Neptune, 10 A.M. EDT

15 The Moon is at perigee (222,109 miles from Earth), 11:38 A.M. EDT

Full Moon is at 11:36 P.M. EDT; total lunar eclipse

21 The Moon passes 5° south of Neptune, 8 A.M. EDT

The Moon passes 3° south of Mars, 4 P.M. EDT

Asteroid Metis is at opposition, 6 P.M. EDT

22 The Moon passes 5° south of Uranus, 8 P.M. EDT

Last Quarter Moon is at 8:31 P.M. EDT

27 Mercury passes 2° south of Venus, 8 P.M. EDT

28 The Moon is at apogee (252,381 miles from Earth), 9:05 A.M. EDT

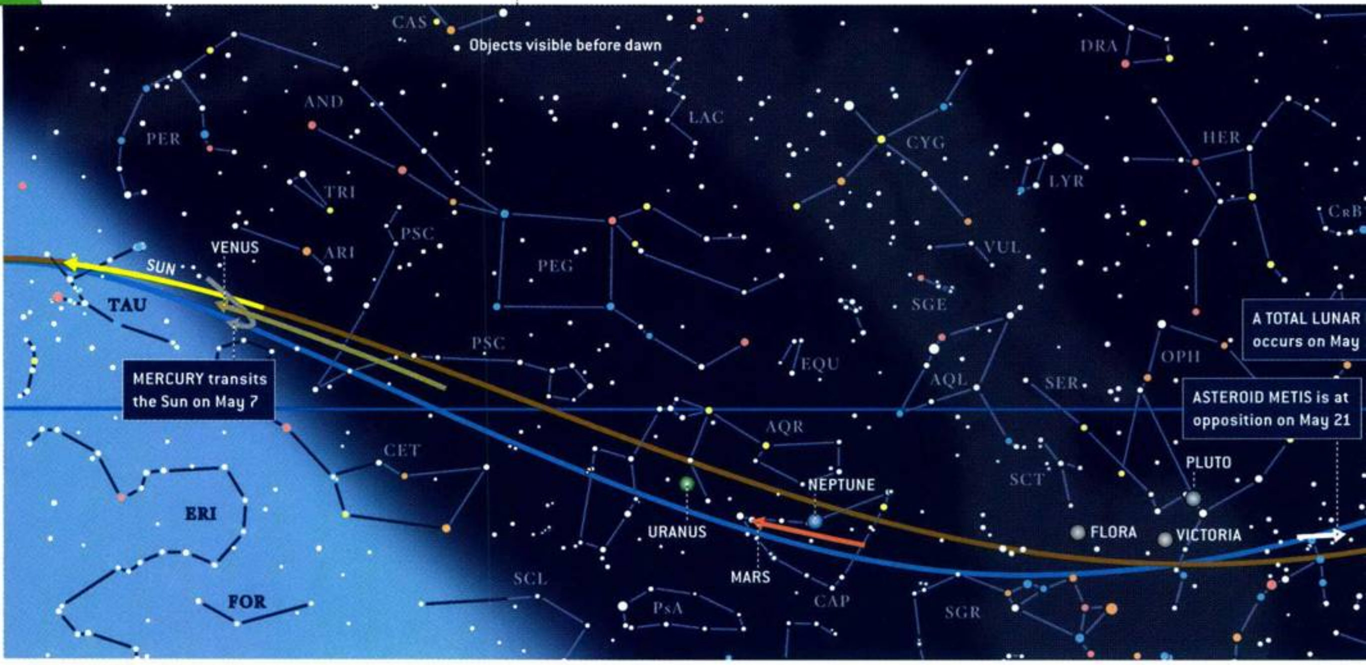
The Moon passes 2° north of Mercury, 11 P.M. EDT

The Moon passes 0.1° north of Venus, midnight EDT

31 New Moon is at 12:20 A.M. EDT; annular solar eclipse

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and sq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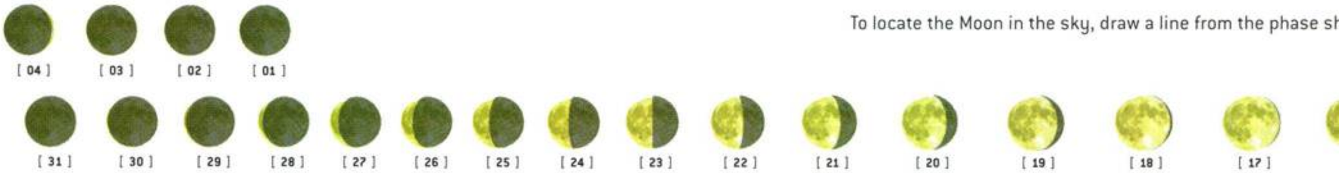
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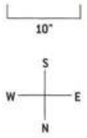
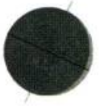
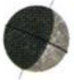
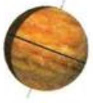
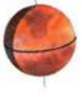
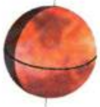
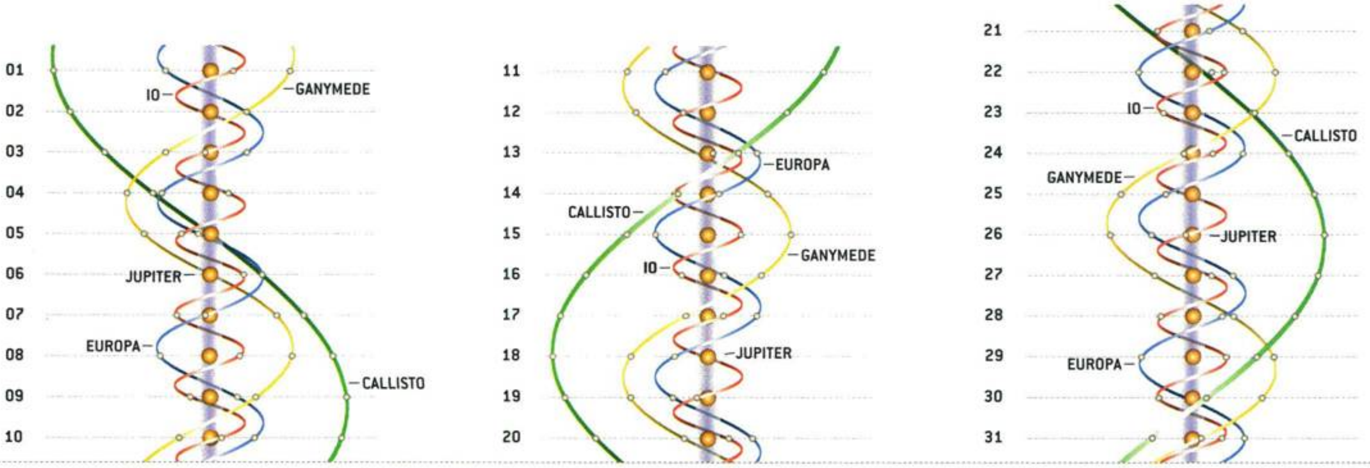
To locate the Moon in the sky, draw a line from the phase sh

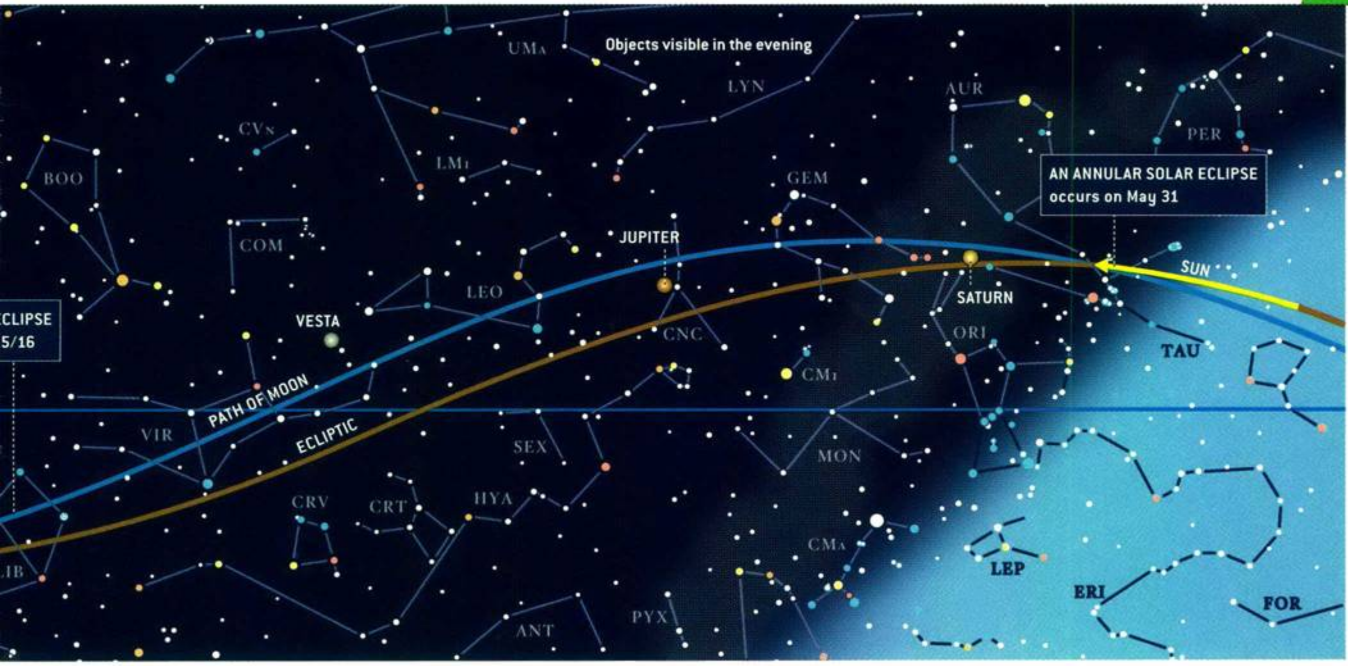
PLANETS 	 MERCURY	 MERCURY	 VENUS	 MARS	 MARS
Date	May 15	May 31	May 15	May 1	May 31
Magnitude	3.4	0.8	–3.9	0.0	–0.6
Angular Size	11.7"	8.8"	11.2"	9.5"	12.3"
Illumination	5%	32%	90%	87%	87%
Distance (AU) from Earth	0.573	0.764	1.493	0.991	0.761
Distance (AU) from Sun	0.465	0.445	0.727	1.472	1.436
Right Ascension (2000.0)	2h41.2m	2h55.6m	1h47.1m	20h32.3m	21h40.8
Declination (2000.0)	13°38'	12°53'	9°18'	–20°23'	–16°44'

Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view in a telescope.



ares show motions and locations of solar system objects during the month.


UMA
Objects visible in the evening
LYN
AUR
PER
CVN
LMI
BOO
GEM
COM
JUPITER
SUN
LEO
SATURN
CLIPSE
5/16
VESTA
CNC
ORI
TAU
CMI
PATH OF MOON
VIR
ECLIPTIC
SEX
MON
CRV
CRT
HYA
CMA
LEP
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FOR
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PYX
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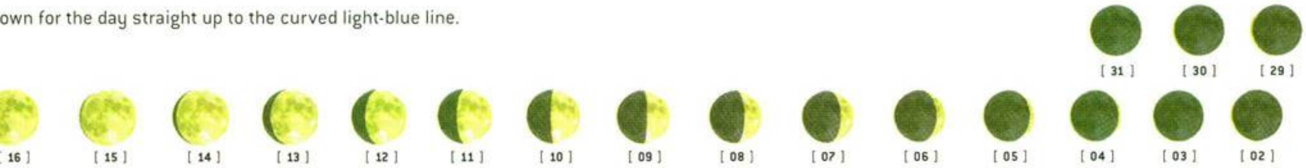
AN ANNULAR SOLAR ECLIPSE occurs on May 31

own for the day straight up to the curved light-blue line.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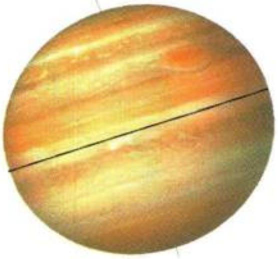
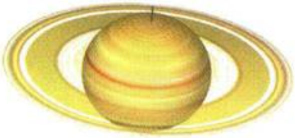
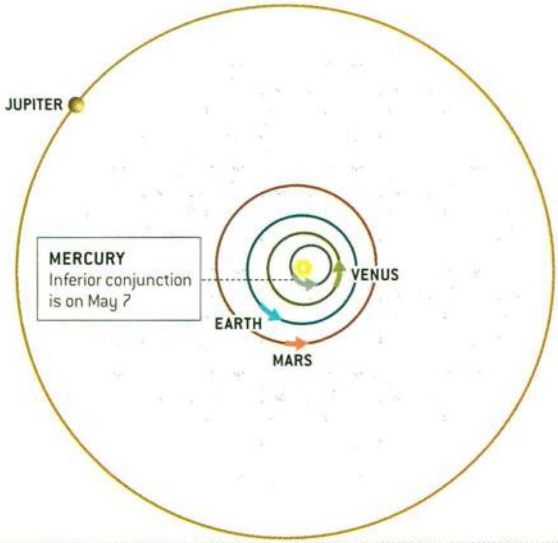




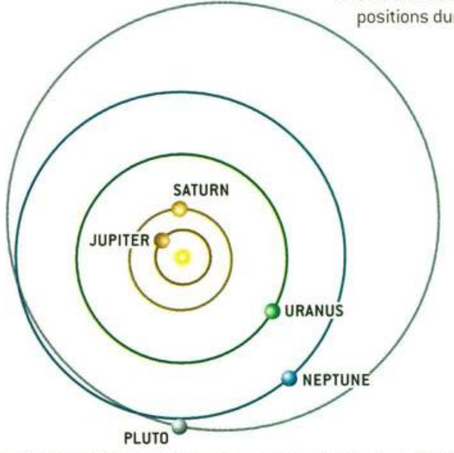
JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
May 15	May 15	May 15	May 15	May 15
−2.0	0.1	5.8	7.9	13.8
35.9"	16.9"	3.5"	2.3"	0.1"
99%	100%	100%	100%	100%
5.485	9.854	20.154	29.879	29.744
5.344	9.031	20.024	30.081	30.647
8h52.7m	5h49.3m	22h19.2m	21h02.4m	17h16.2m
18°24'	22°33'	−11°15'	−16°51'	−13°29'

The planets in their orbits

Arrows and dots show planets' positions during the month.


JUPITER
VENUS
EARTH
MARS

MERCURY
Inferior conjunction is on May 7


SATURN
JUPITER
URANUS
NEPTUNE
PLUTO

THE DEEP SKY

Leo offers a pair of stunning pairs: the colorful double star Gamma Leonis and the galactic couple M65 and M66.

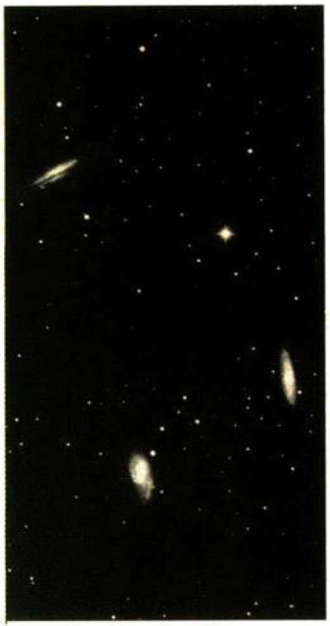
Double gold

After Mizar in Ursa Major and Albireo in Cygnus, one of the favorite double stars of veteran observers is Gamma (γ) Leonis, or Algeiba. Use the circular star map at the center of the magazine to zero in on Gamma, which lies 8° north-northeast of the 1st-magnitude star Regulus. With a small telescope pumped up to 100x, you can easily split this lovely golden pair. Some people describe them as orange, others as yellow — I pick gold. What do you see? If you defocus the image slightly, their colors stand out more boldly.

The brighter component shines at magnitude 2.3, while its companion glows a third as bright at magnitude 3.5. Luckily, they currently lie 4.4″ apart, not far from their maximum separation. With a long orbital period of almost 620 years, we won't be around to see this pair tighten into a real challenge in the 24th century.

On your way to finding the spiral galaxies M65 and M66, stop off at Iota (ι) Leonis, a tighter double star near the limit of a 2.4-inch (60mm) refractor. Just 1.8″ separate the 4.0- and 6.7-magnitude stars, so you'll probably need more than 200x to cleanly split them.

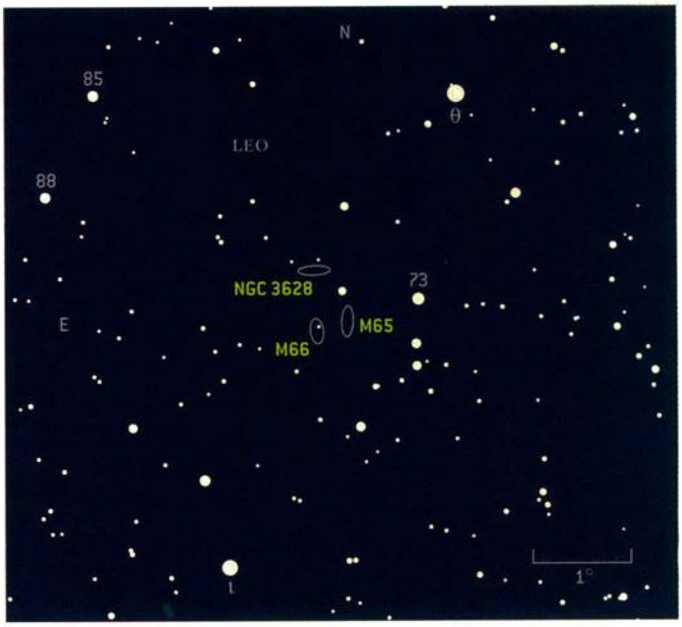
Martin Ratcliffe *is former President of the International Planetarium Society.* **Alister Ling** *is a meteorologist with Environment Canada.*



LEO'S SPIRAL TRIO of M65 (lower right), M66 (lower left), and NGC 3628 (top) form one of the more impressive galaxy groupings in the sky. BILL AND SALLY FLETCHER

A spiral duo

Few galaxies are as easy to find as M65 and M66 in Leo. Point your telescope halfway between Theta (θ) and Iota Leonis and you'll land smack on M65. You can find lots of illusions in space, but this pair is for real. In fact, these two share a gravitational attraction with the nearby galaxies NGC 3628 and NGC 3593.



THE THREE GALAXIES lie about halfway between Theta (θ) and Iota (ι) Leonis. ALL ILLUSTRATIONS BY ROEN KELLY

You won't have any trouble finding M65, which glows at magnitude 9.3, under a dark sky. From a city backyard, however, its oval glow can be a challenge with an 8-inch scope. If you're still at low power, you may spot M66 first because it's a shade brighter and wider. Both galaxies are spiral, with M65 tilted more edge-on to our line of sight.

With at least a 10-inch scope, turn up the power on M66. Far from light pollution, you can begin to see traces of a spiral structure and a mottled, uneven face. Take a picture of it with you, because you may luck into discovering a supernova. These cataclysmic explosions can briefly outshine their entire home galaxy, as happened to M66 in 1973, 1989, and 1997. Give your eyes time to dark adapt and use a dim red flashlight.

Less than a degree north of M66 lies the cigar-shaped NGC 3628, an almost perfectly edge-on spiral. Finding its dust lane usually requires a 10-inch scope operating at a power of 150x or more.

For curious stargazers who want to know more about the objects they observe, Warren H. Finlay has just published a *Concise Catalog of Deep-Sky Objects: Astrophysical Information for 500 Galaxies, Clusters, and Nebulae.* He tells us, for example, that an interaction with NGC 3628 nearly a billion years ago created a plume of gas that extends a quarter of a million light-years from M66.

Although known as Messier objects, M65 and M66 were actually discovered by Messier's assiduous colleague Pierre Méchain on March 1, 1780. Méchain also has eight comets credited to his name.

THE PLANETS

Jupiter and Saturn remain conspicuous in the evening sky, but the highlights of the month are eclipses of the Moon and Sun.

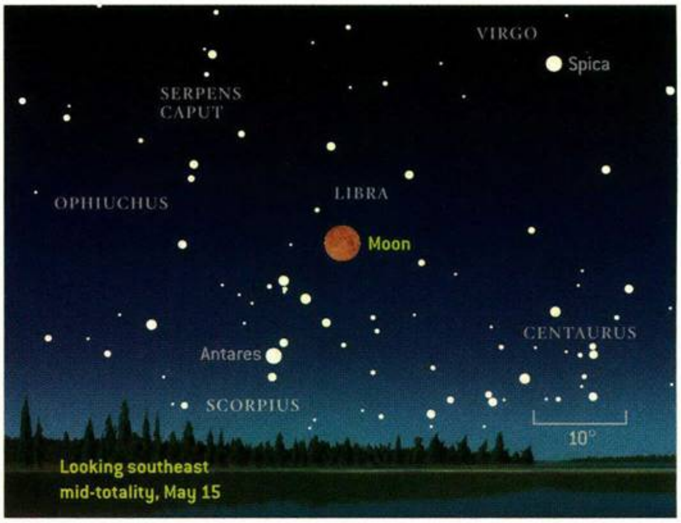
As soon as twilight falls, Jupiter can be seen high in the west-southwest. As the sky grows darker, follow an imaginary line from Jupiter toward the point on the western horizon where the Sun set, and you'll find the dimmer Saturn. This line marks the ecliptic, the apparent path of the Sun and planets across our sky.

Saturn shines at magnitude 0.1 and sets more than three hours after the Sun in early May. By month's end, this window for Saturn-viewing shrinks to about an hour. The planet remains a telescopic gem despite having reached opposition five months ago. Saturn still appears a healthy 17″ across, while its rings span 38″ and tip wide open. Take your final looks at Saturn now because it will pass behind the Sun in June and be lost in the glare.

Jupiter remains in view until well past midnight all month, providing great planetary views on these warm spring evenings. It shines brightly at magnitude –2.0 in Cancer the Crab and offers patient observers a rich quarry of features. To a beginner, the first view of Jupiter presents a brilliant yellowish disk with two dark bands across it. These are the North and South Equatorial belts. Note that most telescopes invert the image, so south appears at top.

Further scrutiny reveals more subtle shading between these two main belts. Additional belts reside between each equatorial belt and the poles. Plumes, slightly darker than their surroundings, erupt from the belts. Dark and bright spots rotate with the planet, a result of dynamic winds that constantly rush around Jupiter.

The most long-lived feature, the Great Red Spot, could be re-christened the Great Salmon Spot for its current, rather mellow hue. It lies at the southern edge of the South Equatorial Belt, and we just don't know if or when it will become more prominent. But we do know that the Red Spot should be around for a while — it's already lasted more than three centuries.



Looking southeast mid-totality, May 15

A RING OF FIRE will hug the horizon in northern Scotland and Iceland on May 31, when the distant Moon eclipses the Sun. PHIL LOHMANN

The rare series of mutual eclipses and occultations involving Jupiter's four bright Galilean moons continues this month. Of the more than 40 events during May, about a third can be seen from North America (though some only from the East or West Coast). See "Shadow Play around Jupiter," December 2002, for details on observing these events. The complete list of events can be found on *Astronomy*'s website at Astronomy.com. Here are a few May highlights:

Europa eclipses Io for a little more than three minutes on May 1, starting at 4:01 A.M. EDT (1:01 A.M. PDT). Then on May 3, Ganymede eclipses Europa for just under three minutes at 2:51 A.M. EDT (11:51 P.M. PDT on May 2). May 13 sees Io occult Europa at 12:13 A.M. EDT (9:13 P.M. PDT on May 12). At the peak of this 4.4-minute-long event, the combined light of the two moons dips by 41 percent.

One of the finest sky events of the year occurs on May 15/16, when the Moon undergoes a total eclipse. On the American evening of May 15, totality begins at 11:14 P.M. EDT, although the action starts well before that. The partial phase, when the Moon first dips into Earth's dark umbral shadow, begins at 10:03 P.M. EDT. After 11:40 P.M. EDT, when the Moon reaches mid-eclipse and lies deepest in the shadow, the stages play out in reverse. Totality ends at 12:07 A.M.

EDT, and the partial phase wraps up at 1:18 A.M. EDT.

At the Moon's distance, Earth's shadow has a diameter more than twice that of our satellite. The Moon passes north of the shadow's center during this eclipse. This results in a darker southern limb, probably a deep red color, compared with the northern limb, more likely to be a bright orange/yellow.

The entire eclipse can be seen from South America and eastern North America. The Moon rises already in partial eclipse for the western half of the United States and rises during totality in Washington state. The United Kingdom, Ireland, France, Spain, and Portugal will see the Moon set shortly after totality ends (on the morning of May 16), while countries farther east will miss most or all of the eclipse.

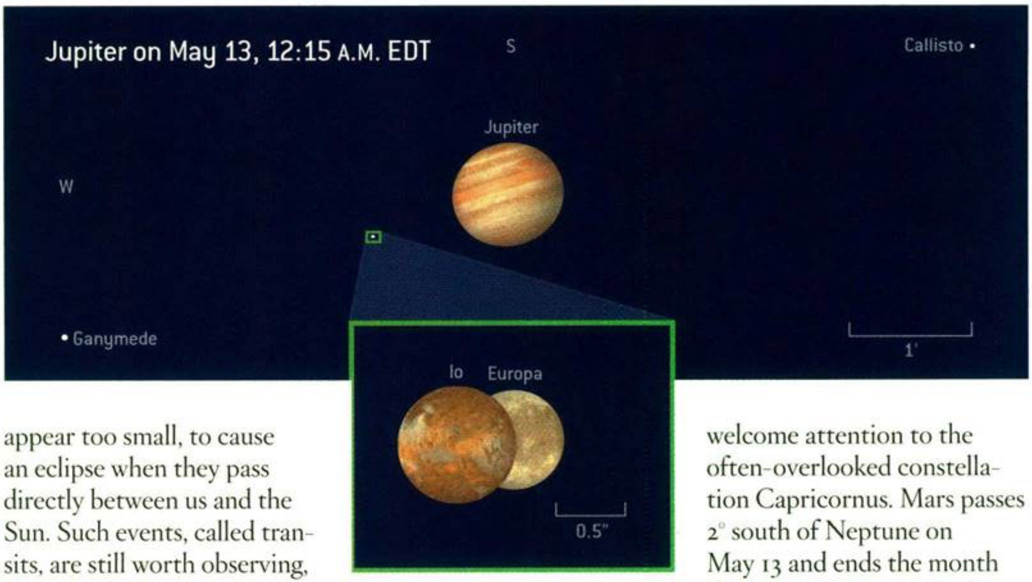
Two weeks later, on May 31, the New Moon casts its shadow on Earth, causing a solar eclipse. Because the Moon lies close to apogee, its farthest point from Earth, it can't fully cover the Sun. The result: an annular eclipse, in which a ring of sunlight remains around the Moon. The annular phase can be seen from a limited area at far northern latitudes, including northern Scotland, Iceland, and parts of Greenland. Remember never to look directly at the Sun without proper eye protection. For more details on both the lunar and solar eclipses, see "Eclipse extravaganza" on page 80.

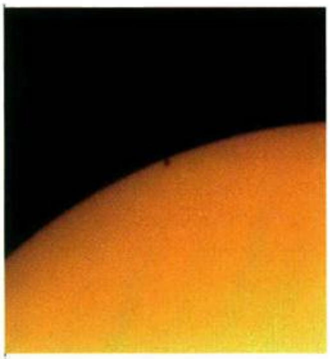
Mercury and Venus lie too far from Earth, and thus appear too small, to cause an eclipse when they pass directly between us and the Sun. Such events, called transits, are still worth observing, however. A Mercury transit occurs on May 7 and can be seen from Asia, Europe, and Africa, with the final stages being visible from northeastern North America. The transit begins at 5:13 Universal Time (UT) and ends at 10:32 UT (6:32 A.M. EDT).

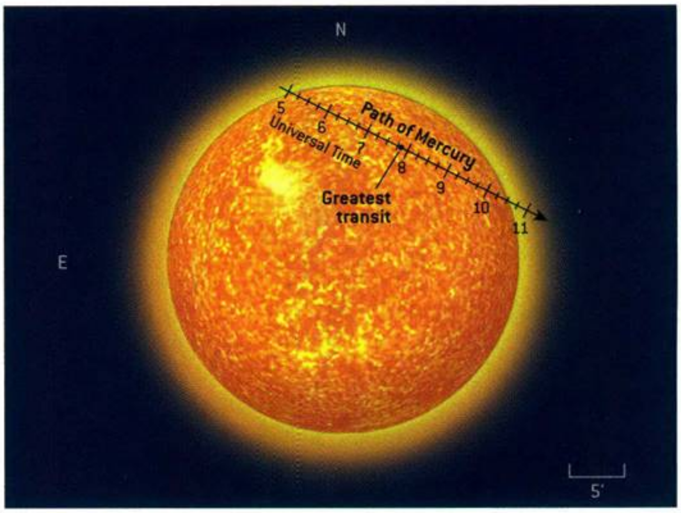
On average, 13 transits of Mercury occur each century, and the next one takes place on November 8, 2006. A similar number of transits of Venus transpires each millennium, making them much rarer. The next one of those comes on June 8, 2004.

After midnight, at about the time Jupiter sets in the west, **Mars** rises in the east. It is moving closer to Earth with each passing week. The latter half of May sees the disk of Mars subtend more than 10″, an apparent size that will double by late July. The planet brightens by 70 percent this month, reaching magnitude −0.6 on the 31st. Such a brilliant, ruddy object brings welcome attention to the often-overlooked constellation Capricornus. Mars passes 2° south of Neptune on May 13 and ends the month close to the 3.7-magnitude star Gamma (γ) Capricorni.

Venus hangs low in the east shortly before sunrise. It shines at magnitude −3.9, and its 11″-diameter disk appears 90-percent lit in mid-May. **Mercury** joins Venus at the end of the month, but it's hard to see. On May 28, see if you can spot the 1st-magnitude planet less than 3° south of Venus. A slender crescent Moon lies 7° west of Venus, providing a brief but lovely sight as the day breaks.


Jupiter on May 13, 12:15 A.M. EDT





MERCURY CROSSES THE SUN'S FACE on May 7 (right), taking a slightly more central path than it did during the November 1999 transit (above). STEVE R. JACKSON

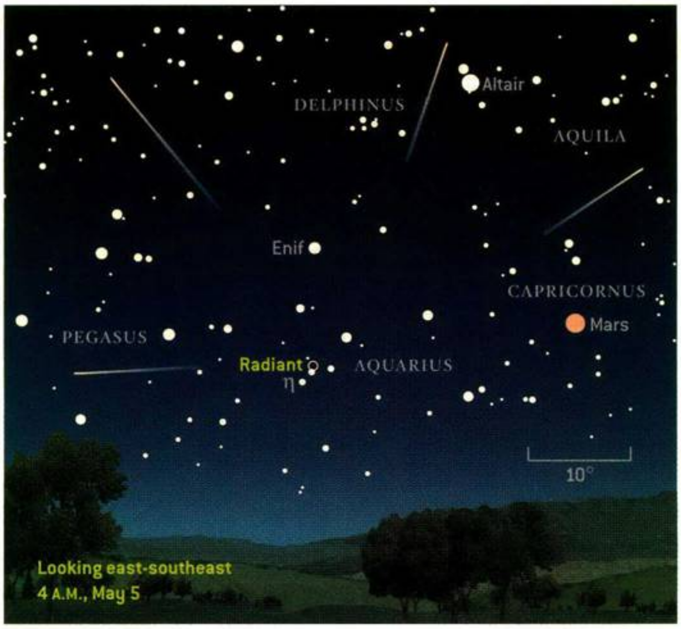
METEORS AND MOONS

Dust particles ejected from Comet Halley will light up the predawn sky as the Eta Aquarid meteor shower peaks during the dark of the Moon.

Eta Aquarids

Famous for its link to Comet 1P/Halley, the Eta Aquarid meteor shower is a favorite among meteor observers. The orbit of this trail of debris closely matches that of the famous comet. The shower peaks on May 5, although it's a broad peak, so many meteors streak the sky a few days before and after.

If the radiant appeared directly overhead, you could expect to see up to 60 swift meteors per hour under a dark sky. Unfortunately, the radiant rises only an hour or so before morning twilight begins, significantly reducing the number of meteors. (In the Southern Hemisphere, however, the radiant lies high, making the Eta Aquarid the top meteor shower.) The best time to view is from 4 A.M. local daylight time until dawn. Look for frequent persistent trains, a glowing trail left over from fast-moving debris vaporizing in our atmosphere about 80 miles up. The Moon is out of the way in early May, helping this year's view of Halley's dusty debris.



Moon feature: Cassini

This fine, complex crater can be found at the southern end of the lunar Alps (Montes Alpes), to the southeast of the prominent crater Plato. The lava plains of Mare Imbrium surround this ancient, 35-mile-wide (57-km) crater to the south and west, and lava has even breached Cassini's southern wall. Two fresher craters, named Cassini A and B, lie inside the fractured walls of the main crater, testifying to its great age.

With a diameter of about 10 miles (17 km), Cassini A is the larger of the two younger craters. It lies off-center in the main crater, while the smaller Cassini B appears near the southwestern wall. Mountainous terrain surrounds Cassini, casting fascinating shadows at low Sun angles, and the famous Alpine Valley lies nearly due north of the crater. The Sun rises over this region a day before First Quarter phase.

Jupiter's satellites

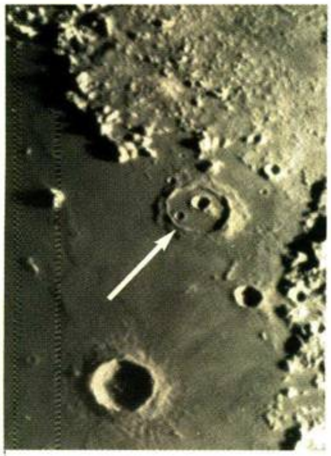
The rare eclipses, occultations, and transits involving Callisto, the outermost Galilean moon, continue this month. During each 12-year orbit of Jupiter around the Sun, only two series of these events occur. The current one began in late 2001 and runs until September 2004. The events listed in the table to the upper right are given in 24-hour format in both Universal Time and Eastern Daylight Time.

Events that occur on either side of midnight are shown twice because the date changes depending on whether you live in Europe or North America. Tr = transit; I = ingress; E = egress; Oc = occultation; Sh = shadow transit; Ec = eclipse; D = disappearance; R= reappearance. The events are worth viewing due to their relative rarity. Not all events are visible from the United States.

/// MAY CALLISTO EVENTS

	{ UT }	{ EDT }	{ Event }
5		20:50	IV.Oc.D.*
6	0:50		IV.Oc.D.*
	5:44	1:44	IV.Oc.R.
	13:05	9:05	IV.Ec.D.
	17:56	13:56	IV.Ec.R.
14	11:30	7:30	IV.Tr.I.
	16:17	12:17	IV.Tr.E.
	23:12	19:12	IV.Sh.I.
		23:44	IV.Sh.E.*
15	3:44		IV.Sh.E.*
22	19:33	15:33	IV.Oc.D.
		20:27	IV.Oc.R.*
23	0:27		IV.Oc.R.*
	7:09	3:09	IV.Ec.D.
	11:59	7:59	IV.Ec.R.
31	6:29	2:29	IV.Tr.I.
	11:16	7:16	IV.Tr.E.
	17:14	13:14	IV.Sh.I.
	21:56	17:56	IV.Sh.E.

*Events that occur on either side of midnight are shown twice.



THE FLOODED CRATER CASSINI, with its two small, embedded craters, stands at the southern terminus of the lunar Alps. LEO AERTS

COMETS AND ASTEROIDS

While the asteroid Vesta remains a bright evening target, two fading comets give their final hurrahs as they head out of the inner solar system.

A LONG ION TAIL highlighted the appearance of Comet C/2002 X_5 (Kudo-Fujikawa) as it approached the Sun last January. MICHAEL JÄGER

Two comets bid adieu

This past winter and spring gave us a simultaneous view of two very different comets, one that faded slowly and quietly, the other roaring to life and then burning out. Comet C/2002 X_5 (Kudo-Fujikawa) exploded onto the scene in mid-December and took a blazing hairpin turn around the Sun. Had last December's total solar eclipse occurred in early February, the comet would have been visible to the naked eye during totality.

There's a reasonable chance nothing may be left of C/2002 X_5 by the time you read this. Small comets that pass too close to the Sun often split apart and disappear in a matter of days. If it survives, look for it in Monoceros, soon after nightfall in the west. You'll need a nice dark sky at the start of the month and a moderate-sized telescope (8 inches or larger) because any remnant is going to be faint. The same goes for C/2001 RX_{14} (LINEAR). Now on its outbound leg, this comet should glow at 12th magnitude. It is dimmer than the faintest Messier deep-sky objects, which are always good reference marks.

Once you point your scope at the coordinates given in the tables at the top right of this page, increase the magnification to more than 100x, and for 10-inch scopes past 150x. This helps to darken the sky background and make the small fuzzies easier to see.

Vesta's easy visibility

In complete contrast to tough comets, you can follow the big asteroid 4 Vesta with binoculars from a city backyard. At magnitude 6.4 in early May, it stands out in a relatively sparse area of sky. Use the background stars Omicron (o) and 12 Virginis to monitor Vesta's slow southward movement from night to night. Should you be blessed with eagle eyes, try to spot Vesta with the unaided eye under a dark sky. Not many people can claim this feat because Vesta doesn't reach naked-eye visibility all that often.

Telescopically, Vesta holds little interest because it looks like a star. In the Moon-free nights of early May, however, it grazes a mere 4′ past the 11.4-magnitude spiral galaxy NGC 4178. In comparison, the Moon spans about 30′. You can even see Vesta move during a single night.

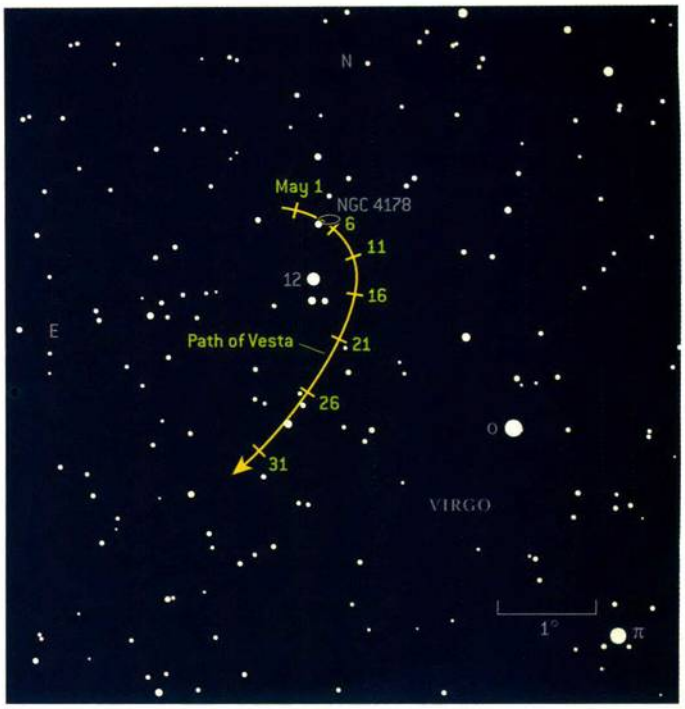
/// MAY COMET POSITIONS

COMET C/2002 X_5 (KUDO-FUJIKAWA)

May	{R.A.}	{Dec.}
1	6h17.1m	0°02'
6	6h25.0m	0°56'
11	6h32.5m	1°43'
16	6h39.7m	2°22'
21	6h46.6m	2°56'
26	6h53.2m	3°25'
31	6h59.7m	3°49'

COMET C/2001 RX_{14} (LINEAR)

May	{R.A.}	{Dec.}
1	11h00.5m	17°35'
6	11h02.0m	15°50'
11	11h03.9m	14°09'
16	11h06.4m	12°31'
21	11h09.3m	10°57'
26	11h12.5m	9°26'
31	11h16.1m	7°58'



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ETX 90EC 1250mm f/13.8 w/UHTC	$545
ETX 105EC	$695
ETX 105EC w/UHTC	$799
ETX 125EC 1900mm f/15	$895
ETX 125EC 1900mm f/15 w/UHTC	$990
#883 Deluxe ETX Field Tripod (90/105/125)	179
#884 Deluxe ETX Field Tripod (90/105/125) w/carrying bag	200
#64 Photo Adapter f/ETX (90/125)	34.95
#825 8x25 Right-Angle Viewfiinder (90)	49.95
#880/#881 Equatorial Table Tripod (90/125)	29.95/59.95
#932 45° Erecting Prism (90/125)	49.95
#1244/#1247 Electric Focuser (90/125)	119.95
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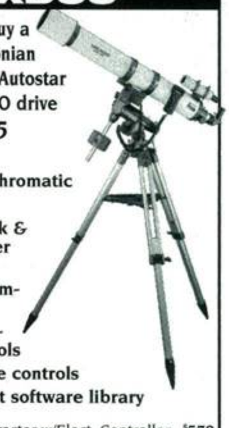

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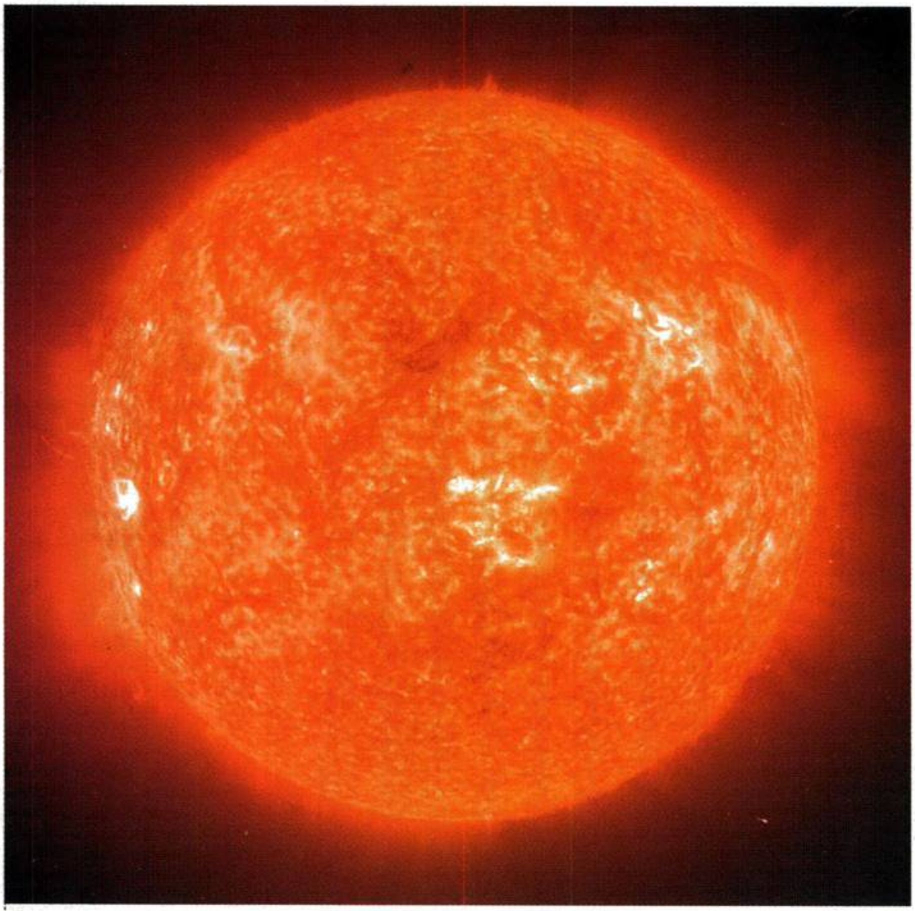
SPACE TRAVEL

If I could find something solid that could withstand the temperatures of the surface of the Sun (highly doubtful, I know), would it sink in or would it be able to float or stand on the surface? — **MARIE BIEMESDERFER,** CHICAGO, ILLINOIS



HOT GASES IN THE SUN'S CORONA are evident in this image taken by the SOHO Extreme Ultraviolet Imaging Telescope on January 2, 2003. THE SOHO EIT CONSORTIUM

The only way something could actually float on the Sun would be to displace a weight equal to that of the floating body. The gases of the outer layers of the Sun are far too light to allow anything you would think of as a solid body to float. Providing it could withstand the temperature (which it could not), it would sink far below the solar surface until it encountered an appropriately dense layer, which would be vastly too far down for you to actually see it. That is, you couldn't "stand on the Sun," which makes calculations of a person's weight on the Sun a bit silly.

That said, things can in a sense float on the Sun and other stars. A high resolution view of the solar surface shows it to be granulated, consisting of a million or so bright "rice grains" that are separated by dark lanes. The granules, which are about the size of a large U.S. state, come and go in only a few minutes and are the tops of convection cells — light, heated gases that rise and float in the solar atmosphere. The gas radiates its energy, cools, becomes denser, and then sinks.

In cooler stars, tiny solid dust grains can survive and can not only float, but can be pushed outward, elevated by radiation pressure. Old dying stars like Mira eventually surround themselves with these tiny particles. In the very coolest stars, the metals in the gases can form fine mineral dust that seems to create floating "clouds" of a sort. The Sun is too hot for such to happen, however. Anything dropped into it would simply plunge out of sight, assuming it could even survive. — **JIM KALER,** UNIVERSITY OF ILLINOIS

AXIAL TILT

Considering the relatively large mass of the Moon compared to the mass of Earth, why does Earth's axis still incline 23° to its orbit around the Sun? One would have thought that the Moon orbiting Earth for many billions of years would have by now evened out Earth's axial tilt to nearly zero. — **RAMON HARTOPP,** KENT, ENGLAND

Actually, the effects of Earth's large Moon can't pull our planet's axis upright or greatly change its tilt relative to Earth's orbit around the Sun. Instead, the Moon's gravity makes the rotation axis precess, causing the celestial poles to trace large circles on the sky, with one circuit taking roughly 26,000 years. Here's how it happens . . .

The spinning Earth isn't a perfect sphere; instead, it's wider at the equator than the poles. The gravity of the Moon and Sun pull on this equatorial bulge, generating a twisting force scientists call torque. Over the monthly lunar orbit and our annual orbit of the Sun, this twisting force makes the direction of Earth's spin axis change without altering its inclination. The technical term for this is precession, and the effect is like the wobble you see with a toy gyroscope, or a child's top, as it spins.

If the orbits of the Moon and Earth didn't change, Earth's spin axis would precess uniformly, and its obliquity — the angle between the equator and its orbit — would remain at the present value of 23.44°. But Earth's orbital plane doesn't remain fixed in space, thanks to the gravitational disturbance of other planets.

As these tug and pull on Earth, they change our planet's orbit minutely. The precession of Earth's spin axis tries to follow these changes but never really catches up. Kept perpetually out of alignment, Earth's obliquity changes in a complex way over thousands and millions of years. The average precession period (one "wobble") is 25,700 years, with the obliquity varying between about 22° and 24½ °. At present the obliquity is larger than average and is decreasing by 0.47 seconds of arc per year. Yet, over long time spans, the rate will vary in amount and numerical sign.

Over very long time spans, another effect on the obliquity has to be taken into account. Tides raised on Earth dissipate energy. This causes Earth's day to lengthen and the Moon to recede. The decreasing spin very slowly reduces Earth's oblateness and lengthens the precession period. Tidal friction also causes a very small drift in obliquity which, for the present shape of the oceans, will increase by only a few millionths of a second of arc per year.

Changes in the planetary orbits, the increasing lunar distance, and changes in the Earth's spin rate and shape all combine to give Earth's obliquity a very complex history. — **JIM WILLIAMS,** JET PROPULSION LABORATORY

THE LARGE MAGELLANIC CLOUD is the closest big extragalactic neighbor to our Milky Way Galaxy, at a distance of approximately 170,000 light-years. U.K. SCHMIDT TELESCOPE

MILKY WAY

What would the Milky Way look like from a planet in the Large Magellanic Cloud? Size? Brightness? Angle of view? — RENE BELZILE, QUÉBEC CITY, QUÉBEC, CANADA

The Large Magellanic Cloud resides in the southern hemisphere of our sky at a distance of about 50 to 55 kiloparsecs — let's call it 170,000 light-years. But the LMC also lies in the Milky Way's southern hemisphere, about 33° off the plane of our galaxy. This means the view of the Milky Way from the Large Magellanic Cloud would resemble in overall form our view of the Andromeda Galaxy. Andromeda is tilted only about 15° from edge-on, so from the LMC the Milky Way would appear as an oval about twice as fat.

A more striking aspect, however, would be the Milky Way's apparent size. The diameter of the Milky Way is often said to be 100,000 light-years; from the LMC this would appear about 30° long and less than half as wide. (From here, Andromeda extends about 3° in length.) But the Milky Way probably reaches outward somewhat farther than the round 100,000 light-year figure, so its faintest parts would extend an even greater distance, though just how far is hard to say.

How bright would the Milky Way look? A rough apparent magnitude would be about –3, between the brightness of Jupiter and Venus at their brightest (although both of these appear as points of light, not the broad swath the Milky Way would present). By comparison, the LMC from Earth covers a circle nearly 10° in diameter, and the combined light of its glow is about 1st magnitude.

Perhaps the most spectacular thing about viewing the Milky Way from the LMC would be the grandstand seat you would have for looking at the center of the galaxy, with its (probable) bar and luminous nuclear region, which are obscured from view at visible wavelengths from Earth. LMCers could also see the spiral arms of the galaxy on the far side of the galactic center from Earth, again completely obscured from our view.
— **BRIAN SKIFF,** LOWELL OBSERVATORY

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Michael E. Bakich is the most recent addition to the editorial staff of *Astronomy* Magazine. Michael's most recent book, *The Cambridge Encyclopedia of Amateur Astronomy*, is due out in May.

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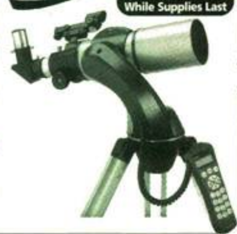

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Coma Berenices

Messier objects and members of the Coma-Virgo galaxy cluster highlight the deep-sky views within Berenice's Hair. /// BY TOM POLAKIS

In spring, the Milky Way encircles us along the horizon, turning the rest of the sky into a large, clear window for viewing distant galaxies. The north galactic pole, that point in our sky farthest from the plane of our galaxy, is located in the constellation Coma Berenices, Berenice's Hair. Despite being a mid-sized constellation, it contains no fewer than eight Messier objects and dozens of bright, nearby galaxies of the Coma-Virgo galaxy cluster. Several globular clusters in the Milky Way's halo also make their home in Coma Berenices.

Coma Berenices is a poorly defined constellation with only three stars brighter than magnitude 4.5. Find it by looking for a large right triangle between the tail of Leo and Boötes. At the northwest corner of this triangle is Gamma (γ) Comae Berenices, a yellowish star 170 light-years away that shines as brightly as 40 Suns. While not a cluster member, Gamma is superposed on the northern edge of **Melotte 111**, also known as the Coma Berenices star cluster, which appears as a sprinkling of a dozen stars brighter than 6th magnitude. Only 300 light-years away, the cluster occupies a diameter of more than 4°. Low-power binoculars or a finder scope yield the best view. Consider how well-camouflaged this cluster would be if it were located nearer to the galaxy's plane.

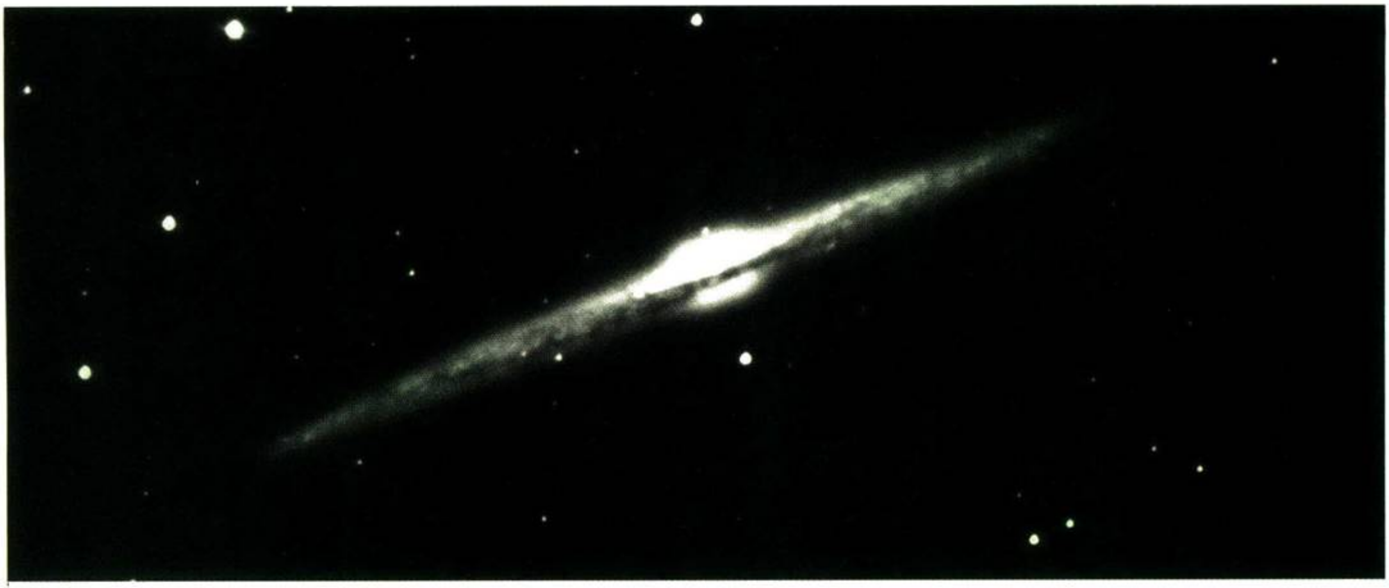
About 10° south of the Coma Berenices star cluster we find a concentration of bright galaxies that are members of the Coma-Virgo galaxy cluster. These galaxies are 50 to 60 million light-years away. The large cluster has two major components: a southern clump surrounding M49 and a northern one around M87. The bright galaxies in southern Coma Berenices are members of this latter component.

Our first Coma-Virgo Cluster galaxy is **M98 (NGC 4192)**, a spiral inclined 16° from our line of sight. Visually, it's a bright spindle 7′ long and a third as wide. A stellar nucleus blazes inside an intense core region 30″ in diameter. The core is flanked by enhancements from associations of stars in the spiral arms. A 13th-magnitude star lies 3′ north of the core.

M99 (NGC 4254) is an inclined spiral known for its strong one-armed structure. The south arm is filled with bright star-forming regions while the north arm is weak. This dichotomy is unexplained by optical observations, but radio images show clouds of neutral hydrogen perturbing the spiral from the south. The one-armed appearance is evident in a 13-inch telescope, which shows a bright core 1′ across with the prominent arm wrapping from the east edge to the south. This spiral arm is mottled and ends at a stellar association. The northern arm is barely visible in this aperture and does not wrap as tightly around the core.

MELOTTE 111, the Coma Berenices star cluster, contains about a dozen naked-eye stars sprinkled over a four-degree field. JOHN CHUMACK

Pan less than a degree east to find the galaxy pair featuring the edge-on spiral **NGC 4302**. Oriented north-south, NGC 4302 measures 3′ by 1′ in a 10-inch scope. Its surface brightness is nearly uniform but for a subtle, broadly concentrated core. Less than 3′ east of NGC 4302 is NGC 4298, an inclined spiral of similar type. It measures 2′ by 1′, is slightly brighter than its neighbor, and exhibits a similarly broad central concentration. The two galaxies are separated in space by about 30,000 light-years, similar to the distance between the Sun and the center of the Milky Way. They also serve



NGC 4565 is an edge-on spiral galaxy with a prominent dust lane easily seen running across the galaxy's bulge. BILL AND SALLY FLETCHER

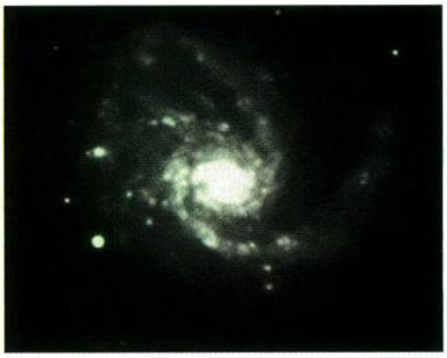
as an example of the Holmberg effect, which is a tendency of paired galaxies to have similar colors and types.

Galaxy-hopping a bit more than a degree to the north brings in **M100 (NGC 4321)**, the brightest spiral galaxy in the Coma-Virgo Cluster. In an 8-inch scope, the overall haze is 4′ by 3′ and bright, but the galaxy does not yield its spiral form easily. Use high magnification and look within a couple arcminutes of the nucleus to find two symmetrical enhancements to the east and west. Larger telescopes begin to show outer spiral structure twice as far from the core. Faint dwarf galaxies are visible just to the north and east of this coiled envelope. To the north, NGC 4322 is a probable companion, but NGC 4328 to the east appears to be in the foreground.

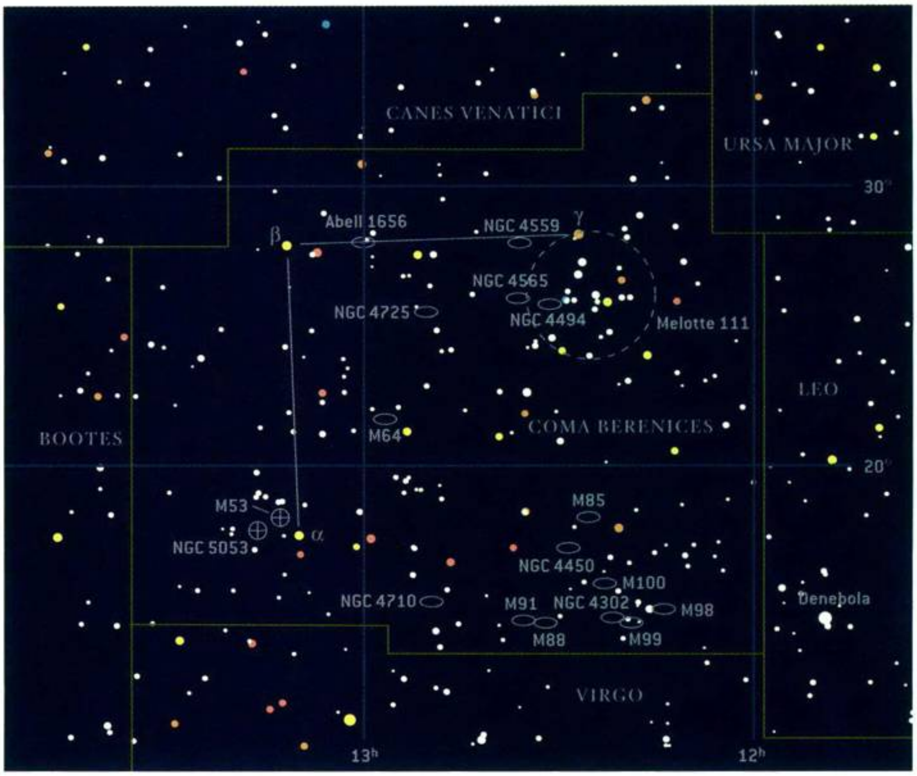
Continuing northward, we come upon **M85 (NGC 4382)**, a bright S0 galaxy. A small scope shows a luminous core surrounded by an oval halo 4′ by 3′ across. Less than 1′ north of the core sits a 13th-magnitude star. Only 8′ east of M85 is the bright barred spiral galaxy NGC 4394, whose bar extends 2′ by 1′ with a very bright center.

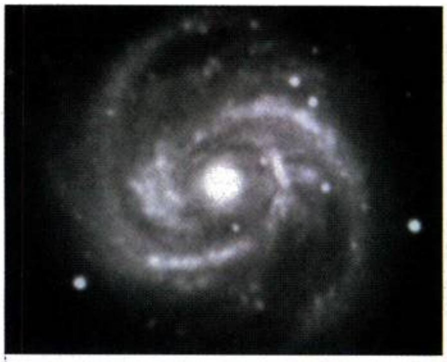
Pan just over 1° to the southeast to bring in the inclined spiral galaxy **NGC 4450**. Its 3′ by 2′ halo surrounds a prominent center. An embedded oval disk 1′ long with a mottled texture appears in large-aperture telescopes.

M98 is a nearly edge-on spiral galaxy with a dusty disk that contains some bright knots of newly formed stars. KIM ZUSSMAN



M99 has an asymmetric structure. One arm is much brighter than the other, and its core lies closer to the brighter arm. KIM ZUSSMAN


CANES VENATICI
URSA MAJOR
30°
Abell 1656
NGC 4559
γ
β
NGC 4565
NGC 4725
NGC 4494
Melotte 111
LEO
BOOTES
M64
COMA BERENICES
20°
M53
M85
NGC 5053
α
NGC 4450
M100
NGC 4710
M91
NGC 4302
M98
Denebola
M88
M99
VIRGO
13h
12h



M100 is one of the first spiral galaxies recognized and is the brightest spiral in the Coma-Virgo galaxy cluster. BILL IBURG

M88 is one of eight galaxies Charles Messier discovered on March 18, 1781. Two stars sit at its southeastern end. JIM RIFFLE

We continue southward toward the heart of the Coma-Virgo Cluster to the bright spiral galaxy **M88 (NGC 4501)**. In a 6-inch telescope, the galaxy looks like a 4′ by 2′ haze surrounding a much brighter nucleus. The size grows to 6′ by 3′ in 13 inches of aperture, and some spiral structure becomes apparent within 1′ of the center. This structure is more evident toward the southeast. In large scopes, look for a pair of 14th-magnitude stars separated by 20″ near the southeastern end of the halo.

Nudging the telescope 1° to the east, the barred spiral galaxy **M91 (NGC 4548)** comes into view. Because Messier gave the wrong relative position for it, M91 was considered "missing" until a few decades ago when Texas amateur astronomer William C. Williams realized Messier must have been referring to NGC 4548. Current research presents compelling evidence that the galaxy has a central supermassive black hole that weighs in at 40 million solar masses. M91 is fainter than most of Messier's finds in this region. Moderate-sized telescopes reveal a faint haze 3′ by 2′ across with a slight central brightening. In a large scope, the bar is visible as a linear feature 4′ long. The spiral arm that extends to the south from the east end of the bar is more readily visible.

NGC 4710 is an edge-on spiral galaxy with interesting structure visible in modest telescopes. In a 10-inch, the moderately bright streak spans 4′ by 1′ in position angle 30°. Directly on either side of a bright central bulge are dark breaks in the spindle surrounded by bright spiral arms viewed along their edge.

Next, we make a long northward slew away from the heart of the Coma-Virgo Cluster back into the Coma Berenices star cluster. **NGC 4494** is an example of an elliptical galaxy with a "kinematically distinct core" — one whose central region rotates very rapidly, and in this case in an opposite sense as the outer region. Visually, it appears moderately bright, about 2′ across, and slightly oval. The galaxy's brightness increases gradually toward the center.

The sky's most spectacular edge-on galaxy, **NGC 4565**, lies 1° east of NGC 4494. An 8-inch telescope reveals a streak more than 10′ long and 1.5′ wide. A large aperture and averted vision seem to cause the galaxy to grow to as long as 15′. Only through apertures of 16 inches or more can the full length of the galaxy be detected out to its very definite ends. The central region features a small bulge, the easiest place to detect the dust lane, which is offset north of center because NGC 4565 is inclined 3.5° from edge-on. A 13th-magnitude star lies just northeast of the core. The galaxy's distance is still uncertain, with recent estimates ranging from 30 million to 50 million light-years. Astronomers suspect that a face-on view of this spiral may resemble M100.

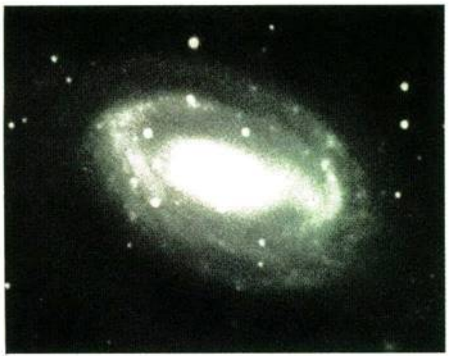
At a distance of 30 million light-years and 17° north of M87, the Coma I galaxy

/// Deep-Sky Objects in Coma Berenices

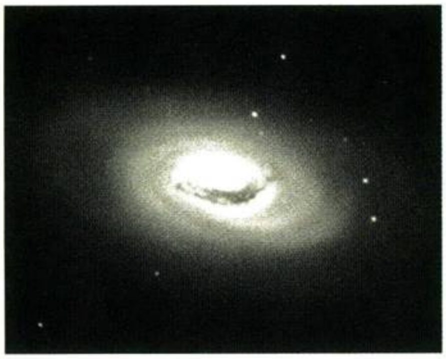
OBJECT	R. A.	DEC.	MAG.	SIZE	TYPE	NOTES
M98 (NGC 4192)	12h13.8m	14°54'	10.1	9.1' by 2.1'	Gal	SAB(s)ab
M99 (NGC 4254)	12h18.8m	14°25'	9.9	4.6' by 4.3'	Gal	SA(s)c
NGC 4302	12h21.7m	14°36'	11.6	4.7' by 0.9'	Gal	Sc
M100 (NGC 4321)	12h22.9m	15°49'	9.3	6.2' by 5.3'	Gal	SAB(s)bc
Melotte 111	12h25.1m	26°06'	1.8	275'	OC	Coma star cluster
M85 (NGC 4382)	12h25.4m	18°11'	9.1	7.5' by 5.7'	Gal	SA(s)0
NGC 4450	12h28.5m	17°05'	10.1	5.0' by 3.4'	Gal	SA(s)ab
NGC 4494	12h31.4m	25°46'	9.8	4.6' by 4.4'	Gal	E1-2
M88 (NGC 4501)	12h32.0m	14°25'	9.6	6.1' by 2.8'	Gal	SA(rs)b
M91 (NGC 4548)	12h35.4m	14°30'	10.2	5.0' by 4.1'	Gal	SB(rs)b
NGC 4559	12h36.0m	27°58'	10	12.0' by 4.9'	Gal	SAB(rs)cd
NGC 4565	12h36.3m	25°59'	9.6	14.0' by 1.8'	Gal	SA(s)b
NGC 4710	12h49.6m	15°10'	11	3.9' by 1.2'	Gal	SA(r)0
NGC 4725	12h50.4m	25°30'	9.4	11.0' by 8.3'	Gal	SAB(r)ab
M64 (NGC 4826)	12h56.7m	21°41'	8.5	9.2' by 4.6'	Gal	SA(rs)ab
Abell 1656	12h59.8m	27°59'	—	319'	Gals	Coma galaxy cluster
M53 (NGC 5024)	13h12.9m	18°10'	7.5	12.6'	GC	
NGC 5053	13h16.4m	17°42'	9.9	10.5'	GC	

Object: Designation in NGC or other catalog. **R. A. and Dec.:** Right ascension and declination in epoch 2000.0 coordinates.
Mag.: Visual magnitude. **Size:** Size in arcminutes or arcseconds. **Notes:** Hubble types for galaxies.

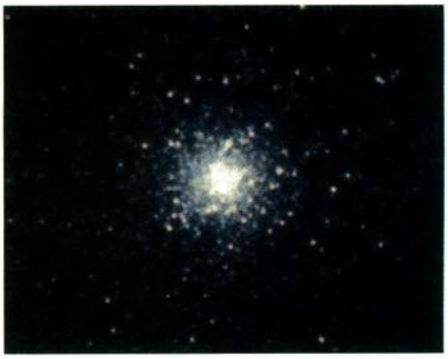
Tom Polakis *is an aerospace engineer in Tempe, Arizona. He enjoys astrophotography and deep-sky observing.*



NGC 4725 is a barred spiral galaxy with an intense core and two bright, opposing arc features in the spiral arms. MARTIN C. GERMANO



M64 is popularly known as the "Black Eye Galaxy" for the curved dust lane on the northern side of the galaxy's core. KIM ZUSSMAN



M53 is a globular cluster located in the halo of our galaxy. It lies about 60,000 light-years from both us and the galactic core. DALE K. BONGES

group contains 30 galaxies. A member of this group, **NGC 4559** is a spiral galaxy 32 million light-years away inclined 20° from edge-on. In a 10-inch telescope, it's faint but interesting. The 3′ by 1′ oval haze is only slightly brighter in the center but punctuated by mottling due to associations in the spiral arms. Three stars of 12th and 13th magnitudes are arranged along the southeastern end.

Moving the scope 3° east brings to view **NGC 4725**, a large, bright spiral galaxy. Interaction with NGC 4747 less than a half degree to the northeast has caused warping in the spiral structure. In a small scope, the galaxy's overall size is 5′ by 2′. A bright oval region 1′ long surrounds a very small and intense circular core. In a larger scope, a tenuous bar follows the long axis and ends in symmetrical, thin arcs that are the brightest regions in the spiral arms. Several superposed faint stars at the northeast end confuse the picture.

Moving to the northeast, the best-studied rich galaxy cluster comes into the field. **Abell 1656** is also known as the Coma galaxy cluster. Hundreds of galaxies in a 4° diameter are centered on the brightest member galaxies NGC 4874 and NGC 4489. Like other galaxy clusters, it formed by the merger of subclusters. One example believed to be falling into the Coma Cluster is a group around NGC 4839 a half degree from the center. The cluster is at least 300 million light-years away. The central elliptical galaxies are two of the most distant objects visually detectable in small telescopes.

While the Coma Cluster subtends 4°, the central half-degree is the richest. Yet, the only members visible in small scopes are the ellipticals NGC 4874 and NGC 4489. At least 8 inches of aperture are needed to give an impression of a galaxy cluster, and then it is only in the form of "lumpy darkness." In a 20-inch, several dozen galaxies are visible as unique objects, though none is larger than 1′. The real excitement of the observation lies in knowing the amount of space and time across which you are looking.

The isolated spiral galaxy **M64 (NGC 4826)** earns its "Black Eye Galaxy" nickname from a prominent dust lane that separates the galaxy core from the northern spiral arm. This structure is visible with averted vision in an 8-inch telescope, where it appears as a 3′ by 1.5′ disk. Large scopes bring the size to 7′ by 3′ by revealing a larger outer halo. With large aperture, thin arm structures appear to encircle the core within the faint halo. The "black eye" is a thin feature, less than 1′ wide and 3′ long.

Our final two objects are globular clusters found by hopping away from Alpha (α) Comae Berenices. **M53 (NGC 5024)** is a poorly studied halo cluster located 60,000 light-years from both the Sun and the Milky Way's center. It spans 6′ in a 10-inch scope and is filled with dozens of 13th-magnitude stars whose numbers rise toward the cluster's broadly concentrated center. It is situated against an unusually sparse star field, which gives good definition to M53's edge.

In the same low-power telescopic field as M53 is one of the Milky Way's least-concentrated globular clusters, **NGC 5053**. Its brightest stars are only slightly brighter than magnitude 14, so it requires an 8-inch scope to resolve well. Visually, this strange globular looks like an open cluster, with only a few dozen widely spaced stars sprayed across a 7′ diameter. Its shape is roughly triangular.

/// BERENICE'S HAIR

'Tis said that Berenice's hair,
In stars adorns the vault of heaven;
But they would ne'er permit thee there,
Who wouldst so far outshine the seven.
To M, *Lord Byron (1788 – 1824)*

The dim stars of Coma Berenices once may have been regarded as part of a larger constellation, perhaps a sheaf of grain held by Virgo or the tip of Leo's tail. But according to a story of love and sacrifice, a Greek astronomer chopped off the small group of stars into its own constellation to comfort an Egyptian queen in the third century B.C.

The wife of King Ptolemy III of Egypt, Berenice was famous for her long, amber hair. Soon after their marriage, the king led his troops into war. Concerned for her husband, Berenice promised the goddess of love (Venus in Roman mythology, Aphrodite to the Greeks) that she would cut off her hair if Ptolemy returned safely to her. When the king did come home, the queen honored her vow and laid her severed locks upon an altar in the goddess's temple.

Berenice became distraught, however, when her sacrificed tresses disappeared. The astronomer Conon of Samos told the queen that the goddess of love had accepted Berenice's offering and placed her hair among the stars, pointing to the small group we now know as Coma Berenices, Berenice's Hair. — *Vanessa Thomas*

May provides an eclipse lover's paradise, with a total lunar eclipse followed two weeks later by an annular eclipse of the Sun. /// BY MARTIN RATCLIFFE

Eclipse extravaganza

A brilliant yellow ring of fire, encompassing an apparent black hole in space, hovers momentarily over the pristine crystal-white beauty of an ice sheet. The fiery ring looks as if it's about to dip into the ice, hanging as it does less than 2° above the horizon, ready to slice the ice sheet in two. It's the May 31 annular eclipse of the Sun, visible from within the Arctic Circle, offering both the poet and astronomer an event of truly spectacular proportions: a "fire and ice" eclipse.

But this month's eclipse excitement doesn't stop there. The solar eclipse, whose partial phases are visible from a wide area of the world stretching from Europe through to Asia, is preceded two weeks earlier by a total eclipse of the Moon, visible from the Americas on May 16. Each eclipse provides fine opportunities both for viewing and gaining a better understanding of the motions of Earth and the Moon. If you happen to be in the path of either eclipse, you won't want to miss it.

Annular eclipse basics

This month's solar eclipse occurs on the 31st. The eclipse is annular, meaning that the Moon doesn't quite cover the entire solar disk, but at mid-eclipse leaves a golden ring of sunlight hanging over the arctic lands. It's an unusual eclipse in many ways; unfortunately, few will get to witness it, due to the remoteness of observing sites and the limited chance of clear skies.

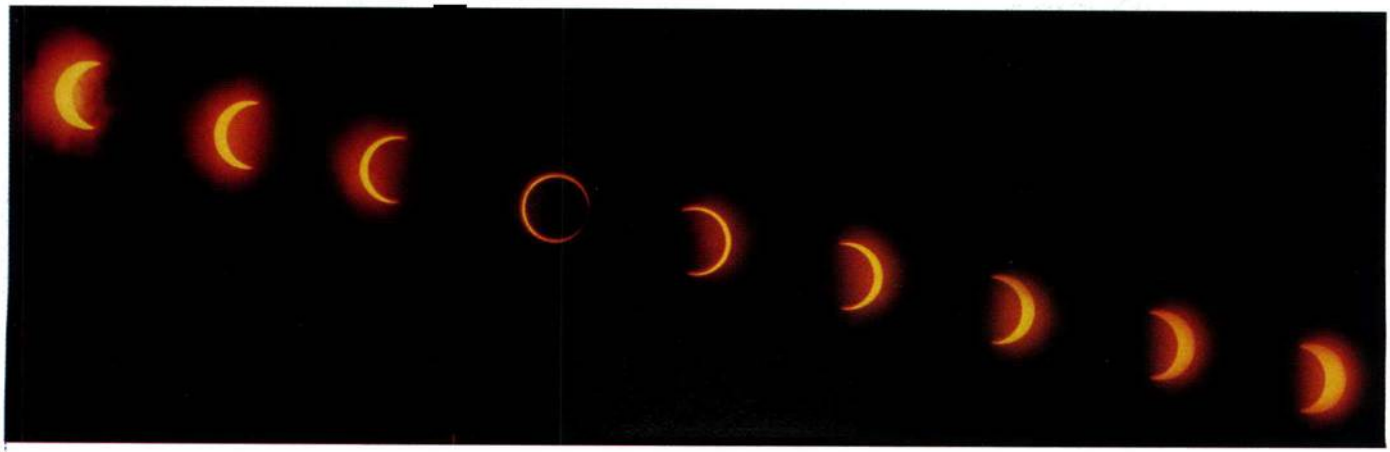
An annular eclipse occurs when the Moon is near its apogee, its farthest point from Earth. The average length of the Moon's shadow is 233,000 miles. The Moon's elliptical orbit causes its distance from Earth to range from 221,400 to 252,700 miles. This means that at apogee the shadow cone will not quite reach Earth. As a result, the Moon passes in front of the Sun but does not quite block it. Centrally located observers will see the black Moon gilded by an intensely bright thin annulus, or ring of sunlight — a "ring of fire." The greatest width of the annulus is only 1⁄20 of the Sun's diameter, or 1½′.

Annular eclipses are perhaps at their most dramatic when the Sun is near a horizon. Of course there's an increased likelihood of being clouded out, but the effect, particularly when the ring of fire is situated over the sea or a sheet of ice, is an unforgettable one.

While annular eclipses are not as spectacular as total eclipses, they have their place in history. The British astronomer Francis Baily first noticed a stunning array of "beads" around the Sun during the annular eclipse of May 15, 1836. His detailed description of their appearance led the glints of sunlight passing through lunar valleys during an eclipse to be called Baily's Beads.

Catch the show

This year's "ring of fire" eclipse occurs over Northern Scotland, Orkney, Shetland and Faeroe Islands, Iceland, and Greenland. A partial eclipse is visible from most of Europe (except Spain, Portugal, and western France), the Middle East, Asia, and Russia. As the shadow crosses the International Date



THIS ECLIPSE COMPOSITE, taken in Malaysia on August 22, 1998, demonstrates how an annular eclipse appears from first contact to the "ring of fire" at totality. MICHAEL AND EUGENE TOH

Line, the last places to see the partial eclipse are on the evening of May 30 in Alaska and northwestern Canada.

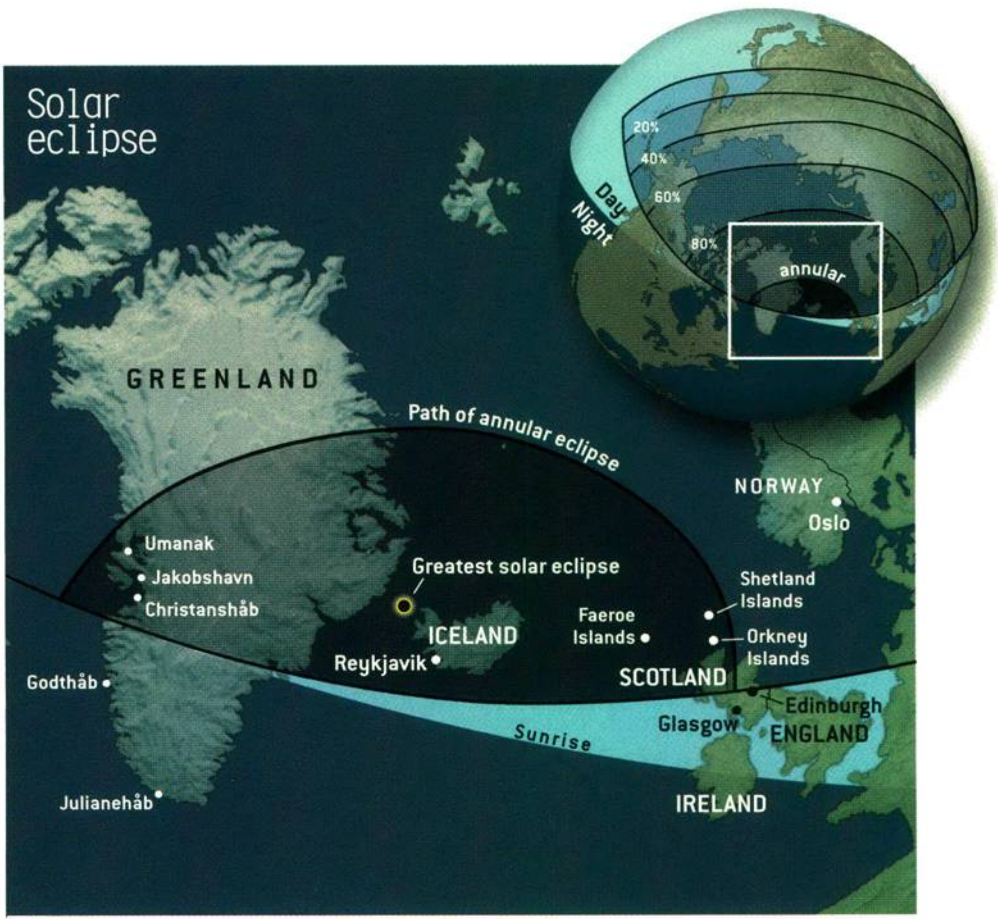
The central shadow, called the antumbra, touches Earth at 4:45 BST in northern Scotland, about 60 miles north of Glasgow. The Sun rises eclipsed at Inverness, and the sky will darken slightly as the annular track runs across Inverness. Ben Nevis, the highest mountain in the British Isles, will see annularity shortly after sunrise. If there are no clouds over Scotland (an event perhaps rarer than the annular eclipse itself), the scene could not be more dramatic, with the ring of fire hanging over the beautiful northern mountains of Scotland.

Observers at Loch Ness will not fare so well, since the Sun will be below the high mountain ridges surrounding that infamous lake, even though it lies within the eclipse zone.

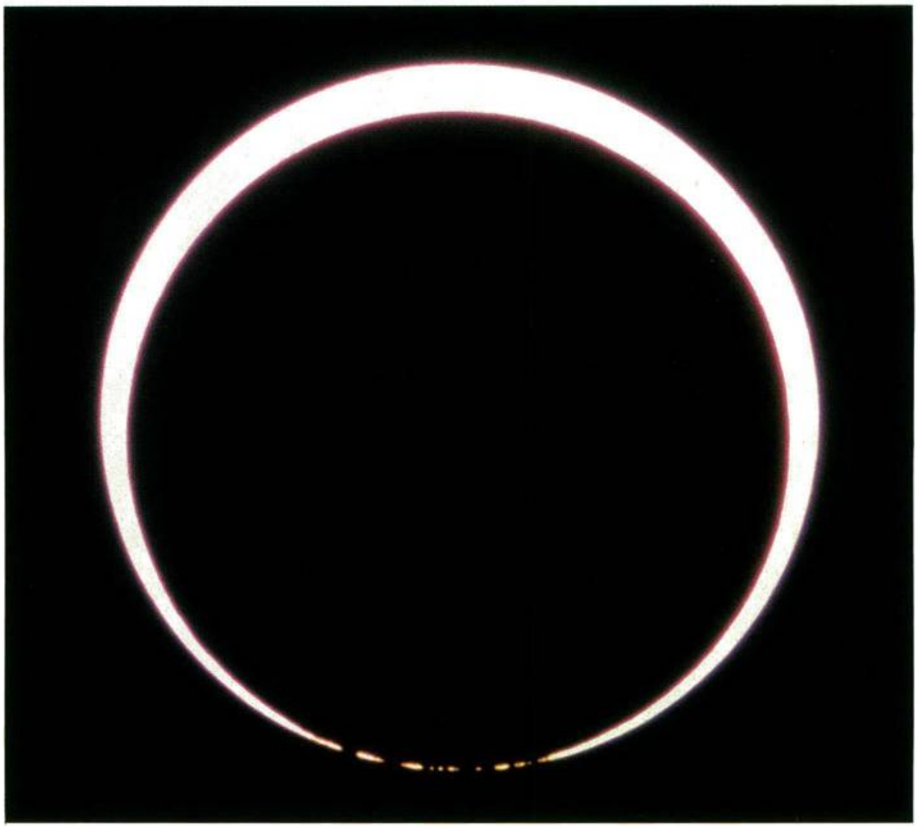
The Orkney and Shetland Islands, and father northwest, the Faeroes, will see the Sun higher in the sky given clear weather. The shadow reaches the Faeroes at 3:51 UT, where the Sun hangs 4° above the horizon. The annular phase lasts 3 minutes 8 seconds. The Moon will not appear exactly centered over the Sun but does offer a chance to see Baily's Beads.

Reykjavic, Iceland, is the only city within the centerline. With a duration of 3 minutes 30 seconds, Icelanders will view the annular eclipse about 2° above the horizon. The shadow touches Iceland at 3:59 UT and reaches Reykjavic at 4:05 UT, when the eclipsed Sun stands above the northeastern horizon as a ring of fire over the snow-covered landscape. The shadow progresses over the Danish Straight, into Greenland, and leaves Earth's surface at 4:31 UT, just 47 minutes after it began its trek westward.

Most of Europe will see the Sun rise on May 31 with the eclipse already underway. Partial phases of varying degrees will be witnessed from a wide range of cities. (See "Local time and circumstances," page 82.) The partial eclipse will be most obvious to citizens of Oslo, Norway, where 91 percent of the Sun's diameter will be blocked by the Moon at 3:41 UT. Eastern European cities and western Russia will experience at least a 60-percent eclipsed Sun, while Iran, Iraq, and Afghanistan experience a 30- to 50-percent eclipse.


Solar eclipse
20%
40%
60%
80%
annular
Day
Night
GREENLAND
Path of annular eclipse
NORWAY
Oslo
Umanak
Jakobshavn
Christanshåb
Greatest solar eclipse
ICELAND
Reykjavik
Faeroe Islands
Shetland Islands
Orkney Islands
SCOTLAND
Godthåb
Edinburgh
Glasgow
ENGLAND
Sunrise
Julianehåb
IRELAND

ANNULARITY will be visible in Iceland and parts of Scotland and Greenland, as well as the Shetland, Orkney, and Faeroe Islands. *ASTRONOMY:* ROEN KELLY



AN ANNULAR ECLIPSE offers observers a chance to see Baily's Beads, such as in this photo, taken in New Mexico on May 10, 1994. ALBERTO LEVY

A curious aspect of this eclipse is that the track of annularity progresses, paradoxically, from east to west, rather than the normal west to east. Because the shadow of the Moon is grazing the northern part of Earth near the June 21 summer solstice, such an oddity can occur. On May 31, Earth's North Pole is tilted sunward by 22.8°, bathing almost the entire Arctic Circle in sunlight for 24 hours. Northern Greenland, for example, experiences a midnight Sun.

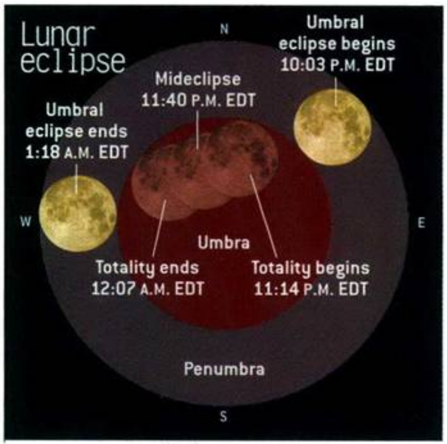
At the time of the eclipse, Iceland and Greenland are in sunlight, beyond the North Pole as seen from the Moon. From a rotating Earth viewpoint, the eclipse takes place on the far side of Earth that is moving in the opposite direction to the sunward side. As the shadow progresses, it consequently appears to move east to west.

Interestingly, the northern limit of the eclipse is Earth's terminator, which lies south of Iceland. The southern limit is, paradoxically, to the north of Iceland, closer to the sunward-pointing North Pole. The centerline, due to this unusual geometry, is not a linear path with parallel sides, as in most eclipses, but a semicircular path that starts and ends at the sunrise terminator.

The next total eclipse of the Sun occurs on November 23 over Antarctica, while the next partial eclipse of the Sun visible from the United States will occur on April 8, 2005.

Lunar eclipse basics

A lunar eclipse occurs when the Moon burrows into the long shadow formed by Earth. Consequently, a lunar eclipse must occur at Full Moon, since only then is it on the shadow side of Earth. Only sunlight filtered by our ultra-thin atmosphere reaches the Moon and bathes it in a dull red-orange glow. An observer on the Moon would see Earth apparently girded by a ring of fire.


Lunar eclipse
N
Umbral eclipse begins 10:03 P.M. EDT
Mideclipse 11:40 P.M. EDT
Umbral eclipse ends 1:18 A.M. EDT
W
E
Umbra
Totality ends 12:07 A.M. EDT
Totality begins 11:14 P.M. EDT
Penumbra
S

TOTALITY lasts for 53 minutes and is visible to observers in South America, the Caribbean, Mexico, the continental United States, and most of Canada. *ASTRONOMY:* ROEN KELLY

While it might seem that an eclipse of the Moon should occur with every Full Moon, because the Moon's orbit is inclined by 5°, it misses the shadow on most orbits around Earth. A lunar eclipse occurs only when the Moon is full and it lies on the ecliptic.

Mark your calendar

Such a wonderful alignment happens on the night of May 15/16. The Moon begins its deliberate plunge into the main umbral shadow at 2:03 UT on May 16 (10:03 EDT May 15 in the United States). Subtle darkening of the eastern edge of the Moon will be noticeable about 30 minutes earlier, signaling the Moon's journey into the penumbra.

The partial phase of the eclipse begins just as the Moon rises along a line running from New Mexico to North Dakota. Cities east of this line will have a full view of the entire eclipse. Earth's shadow at the distance of the Moon spans a little more than two Moon widths. Scientists have known for 300 years that the shadow is fractionally larger than simple geometry suggests. Timing the moment when the center of a crater enters and leaves the umbra is useful to determine its exact size. For large craters, record the moment the shadow reaches each side of the crater

/// Solar eclipse local times and circumstances

CITY	BEGINNING (UT)	MIDDLE (UT)	END (UT)	MAGNITUDE (%)
Anchorage	4:31	5:28	6:21	53
Athens	r	3:08r	3:57	67
Baghdad	r	2:44	3:39	49
Bern	r	3:44r	4:21	61
Brussels	r	3:40	4:28	80
Cairo	r	2:57	3:39	49
Copenhagen	r	3:34	4:33	89
Frankfurt	r	3:28	4:25	87
Glasgow	r	3:47r	4:40	91
Helsinki	2:36	3:36	4:39	86
Istanbul	r	3:03	4:01	70
London	r	3:55	4:32	62
Moscow	2:24	3:25	4:30	77
Oslo	2:43	3:41	4:41	91
Paris	r	3:57r	4:26	50
Reykjavic	r	4:04	5:01	97 Annular
Rome	r	3:41r	4:10	46
Stockholm	2:38	3:37	4:39	88
Tehran	1:53	2:46	3:43	46
Vienna	r	3:20	4:19	83

Magnitude is the percentage of the solar diameter covered by the Moon. **'r'** indicates eclipse is in progress at sunrise.
Data courtesy F. Espenak, NASA GSFC.

Martin Ratcliffe *saw his first solar eclipse from Kenya in 1980. He is co-author of* Astronomy*'s monthly column, "The sky this month."*

and take the average. (For more information, go to www.astronomy.com.)

It takes over an hour for the Moon to be completely engorged by the deepening orange glow of Earth's shadow. Onset of totality occurs at 3:13 UT (11:13 EDT). Totality is visible from South America, the Caribbean, Mexico, the entire continental United States, and most of Canada, except the northwestern reaches. In Spokane, Washington, the totally eclipsed Moon rises just before 8:30 P.M. PDT. In England, France, Germany, Italy, and Spain, the eclipse begins in the early morning hours, with the onset of totality occurring in a brightening twilight sky. In London, England, the Moon sets, totally eclipsed, at 5 A.M. BST (British Summer Time). Totality lasts for 53 minutes, from 11:13 P.M. EDT (May 15) to 12:06 A.M. EDT (May 16).

The totally eclipsed Moon hangs like a Chinese lantern among the stars of Libra. On the far side of the sky, Jupiter stands 27° above the western horizon in Cancer the Crab. Scorpius is rising over the southeastern horizon for the eastern half of the country. Its pincers appear to reach out toward the eclipsed Moon, as if trying to capture a wounded prey. Antares, emulating the eclipsed Moon's color, winks in the atmospheric turbulence of the low southeastern horizon.

A TOTAL LUNAR ECLIPSE will occur over the Americas on May 16. This crimson eclipse was captured at totality on January 9, 2001, from Italy. GIANNI TUMINO AND MELANIA PLUCHINOTTA

Lunar color

How dark will the Moon appear? The darkest eclipses occur when the Moon passes centrally through the shadow. This month, the Moon, also near perigee, slides across the northern part of the shadow. The southern edge of the Moon will appear darkest at mid-eclipse, standing about 9′ north of the center of the shadow. The northern edge of the Moon will appear much lighter, offering a wide range of color with the larger-than-normal Moon (33′ in diameter).

The depth of color on the Moon depends on the state of the thin strip of atmosphere around Earth's limb that sunlight passes through during totality. Excessive volcanic ash in the atmosphere following an eruption can render the Moon a deep red color. Little dust in the atmosphere will result in a bright orange eclipse. Clouds along Earth's limb will darken the eclipse. As the eclipse progresses, look for subtle changes of hues.

In the minutes before 12:06 A.M. EDT, the western limb of the Moon (left side) will begin to brighten as the end of totality approaches. The Moon loses its apparent color quickly as sunlight falls on the Moon's surface once again. The sheer contrast of the sunlit portion makes the rest of the Moon appear as if it is in a dark gray shadow. Over the next 71 minutes the Moon glides gracefully out of the umbral shadow, marking the end of the partial phase of the eclipse. The southeastern limb will appear dusky for a further 30 minutes as it remains within the penumbra.

The next total eclipse of the Moon occurs on November 9, 2003, again visible from the United States and Europe. ■

/// Lunar eclipse times (P.M. denotes May 15, A.M. denotes May 16)

EVENT	U.T.	E.D.T.	P.D.T.
Penumbral eclipse begins	1:05	9:05 P.M.	6:05 P.M.
Partial eclipse begins	2:03	10:05 P.M.	7:05 P.M.
Total eclipse begins	3:14	11:14 P.M.	8:14 P.M.
Greatest eclipse	3:40	11:40 P.M.	8:40 P.M.
Total eclipse ends	4:06	12:06 A.M.	9:06 P.M.
Partial eclipse ends	5:17	1:17 A.M.	10:17 P.M.
Penumbral eclipse ends	6:15	2:15 A.M.	11:15 P.M.

Times rounded to the nearest minute. Courtesy F. Espenak, NASA GSFC.

For a detailed lunar eclipse chart, go to http://www.astronomy. com/toc.

TECHNIQUES

This new multi-use camera allows the budget-conscious observer to explore a universe of digital possibilities. /// BY DAVID HEALY

Three-in-one technology

As amateur astronomy joins the digital age, many new electronic imaging gadgets are targeting the sky. Choosing between a CCD camera and a high-speed video system can be difficult for a budget-minded observer. Now that choice can, for some users, be resolved by a single instrument — the SBIG STV — that has both imaging and video-like capabilities. This new all-purpose instrument can also be used as an autoguider. While not a dedicated imaging CCD, this instrument is versatile, comes packed with software features, and has a large selection of optional accessories to help you best adapt it to your specific needs.

Improving on the past

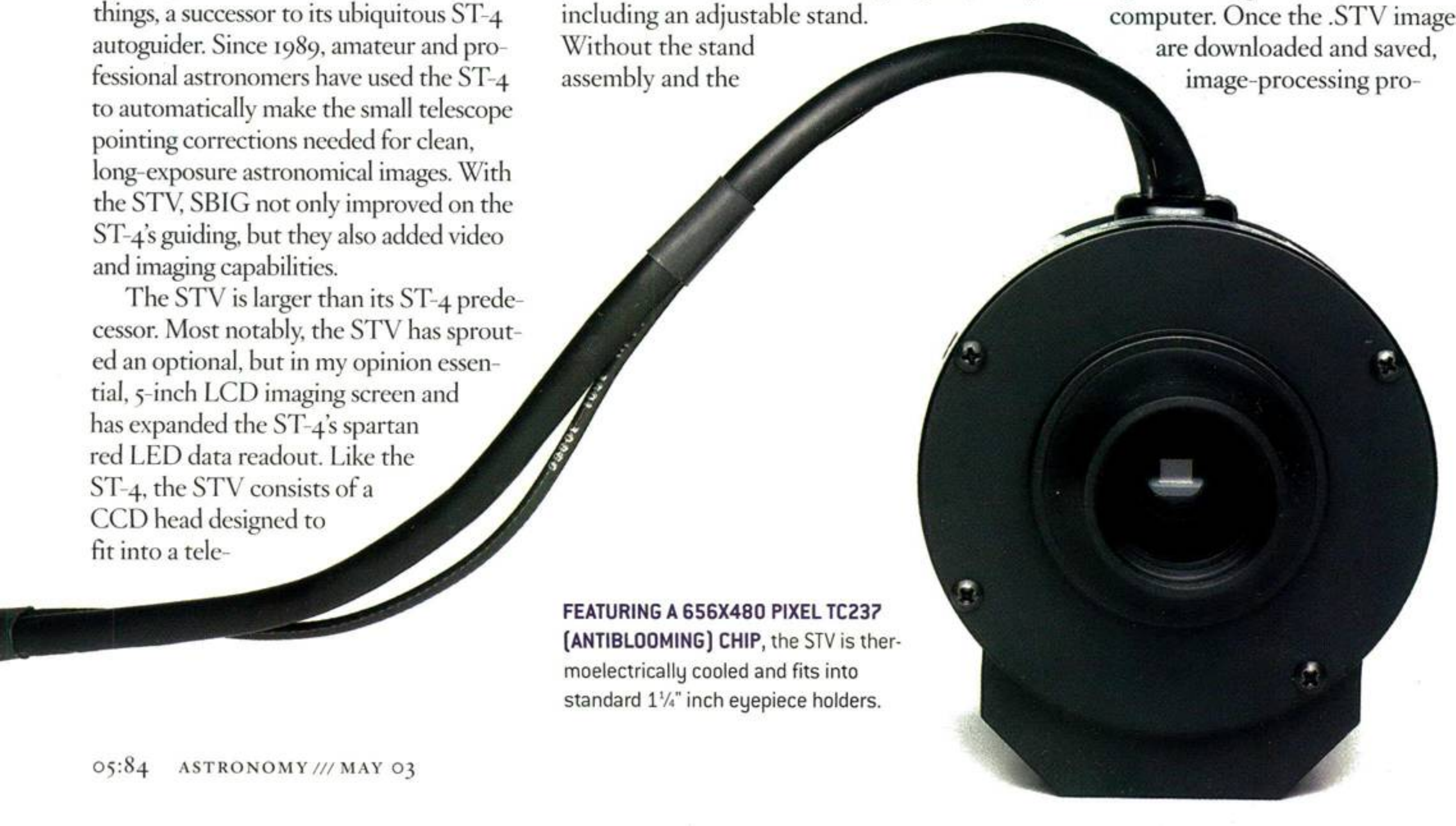
In July 1999, Santa Barbara Instrument Group (SBIG) introduced the STV, a unique product which is, among other things, a successor to its ubiquitous ST-4 autoguider. Since 1989, amateur and professional astronomers have used the ST-4 to automatically make the small telescope pointing corrections needed for clean, long-exposure astronomical images. With the STV, SBIG not only improved on the ST-4's guiding, but they also added video and imaging capabilities.

The STV is larger than its ST-4 predecessor. Most notably, the STV has sprouted an optional, but in my opinion essential, 5-inch LCD imaging screen and has expanded the ST-4's spartan red LED data readout. Like the ST-4, the STV consists of a CCD head designed to fit into a telescope's standard 1¼-inch eyepiece holder and is linked by cable to a control box. The entire assembly operates off a standard 12-volt power supply. For use in the field, a deep-discharge marine battery is recommended. The STV draws 2 amps of current, twice the ST-4's draw, and can drain a car battery over the course of an evening. Also like the ST-4, the STV CCD head is thermoelectrically cooled, but the STV now allows the temperature to be software-controlled.

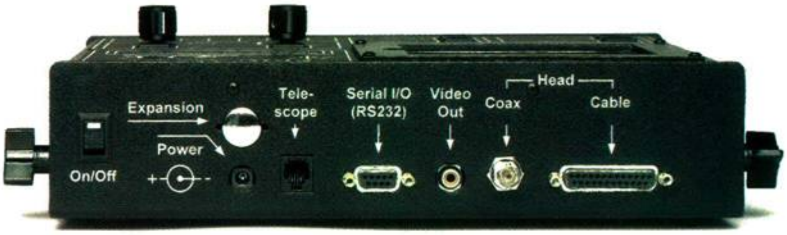
The STV's control box weighs 5 lbs., including an adjustable stand. Without the stand assembly and the front panel's two control knobs, the control box measures about 12″ by 9.5″ by 3″. The STV's 3″ by 3″ cylindrical CCD head, with internal mechanical shutter and imaging chip, has 2.5 times the imaging area of the ST-4 and weighs 19 ounces. The STV kit includes STV REMOTE software as well as CCDSoft5. Updates and software also can be downloaded from SBIG's website.

What the STV can and can't do

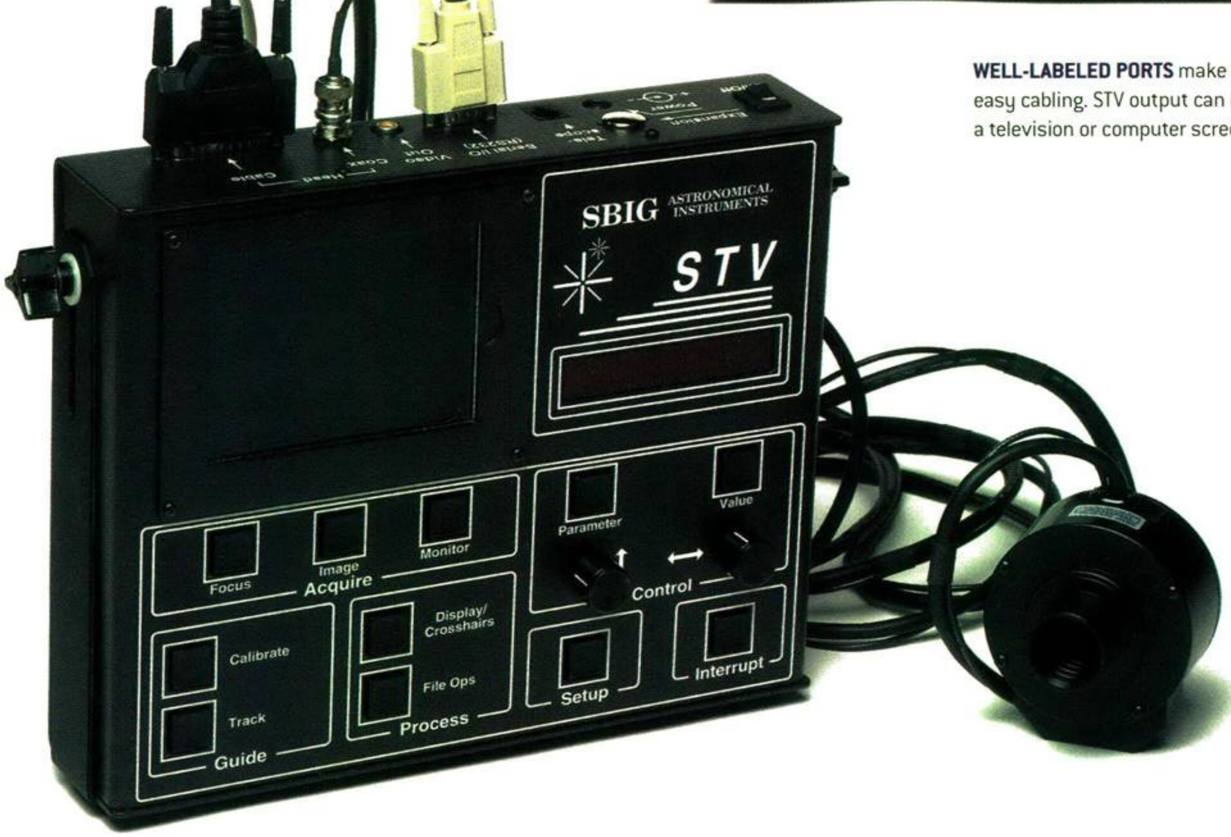
The STV can be operated without a computer. Its internal memory allows the user to save images and recall them to the screen. The STV's 2-megabyte memory can store 14 images in the .STV file format. Images are up to 66 kilobytes in size. To free up the STV's memory for additional images, the user must download previously saved images to a Windows computer. Once the .STV images are downloaded and saved, image-processing pro-



FEATURING A 656X480 PIXEL TC237 (ANTIBLOOMING) CHIP, the STV is thermoelectrically cooled and fits into standard 1¼" inch eyepiece holders.



WELL-LABELED PORTS make for quick and easy cabling. STV output can be displayed on a television or computer screen.



THE STV BY SBIG packs a lot of features into a small package. Pulling triple duty as a CCD imager, autoguider, or digital video camera, this instrument can be used as shipped, or linked to a Windows computer.

grams such as CCDSoft5 (supplied) or MaxIm DL can be used to process, print, and e-mail the images. Both programs can convert .STV files to FITS, bitmap, JPEG, and TIFF file formats.

The CCD also can be operated via a computer linked to the STV control box with a ninepin RS-232 serial cable (supplied) using the STV REMOTE software. STV REMOTE produces a virtual copy of the STV's control panel on the computer monitor, allowing the STV functions to be controlled either remotely from a computer or directly via the two knobs and eleven large buttons on the STV's control panel.

Incidentally, the STV's non-adjustable display screen is too bright for maintaining a user's dark adaptation, and the red "Night Vision" mode is little better. Many users will want to dim the screen with red or neutral-density plastic material to protect their night vision.

From video to imaging

The STV is equipped with a "Video Out" RCA jack, allowing the STV's screen to be displayed alternatively on a TV monitor (NTSC or PAL) or piped to a VCR. This video capability should be particularly useful for demonstrating astronomical imaging to classes or groups, whether it be by showing (almost) real-time images of planets or the Moon, or by watching the image of a spiral galaxy slowly build up while the STV operates in "Track and Accumulate" mode. To accommodate the difference of at least 400,000-fold in brightness between a planet such as Saturn and a typical imaging-target galaxy such as NGC 7331, the STV allows exposure times ranging from 0.001 second to ten minutes, and the signal's gain can be adjusted as well. For imaging extremely bright objects, such as a near-full-phase Moon, the STV CCD head's internal shutter wheel has a green filter that allows users to reduce by a factor of 20 an object's observed brightness.

The STV, however, cannot update or refresh images displayed on its screen as quickly as it can expose them. The fastest image refresh time for the STV is ¼ second when in "Focus" mode. The refresh time is variable and somewhat longer in "Image" mode. For comparison, a video camera has a 1⁄30-second exposure and image-refresh time. In practical terms, however, the STV, when focused on a bright object, displays images virtually in real time.

The STV takes only monochrome images; however, by replacing the STV's standard shutter/filter wheel with SBIG's CFW5C color filter wheel (a $449 option), the STV can merge individual red, green, and blue filtered images to produce color images. The STV's screen can display these color images.

PHOTOS BY JAMES FORBES

THE COMPUTER INTERFACE provides an on-screen replica of the STV's push-button front panel. Transitioning between the two is easy and allows an observer to switch between working in a control room or at the telescope without having to think too hard — a real asset at 5 A.M. DAVID HEALY

Deep-sky imaging

Whether taking "real time" planetary exposures or long-exposure deep-sky images, the STV must be accurately focused before imaging can begin. Focusing is easy using the STV's "Focus" mode. Simply center a bright star in the telescope's field of view and adjust the telescope's focus until the rapidly updating star appears sharpest.

The STV's imaging chip is a Texas Instruments TC237 antiblooming chip, with a 656x480 array of 7.4 micron-sized pixels and overall dimensions of 4.7mm by 3.6mm. The STV's field of view on the sky is 8.0′ by 5.0′.

The STV's focal reducer lens, which I highly recommend, permits much shorter exposure times by converting an 8-inch f/10 system to f/5.95 (13.8′ by 10.2′ field) or f/3.75 (21.9′ by 16.2′ field). The STV images and displays at three levels: wide, normal, and zoom. Set to "wide," the STV uses the entire chip for imaging, but its pixels are binned 3x3, which reduces the image's resolution while increasing its sensitivity. At the "normal" level, the STV images the central 640x400 pixels of the chip, and the pixels are binned 2x2. At the "zoom" level, only the central 320x200 pixels are imaged, but the pixels are at full 1x1 resolution. The STV's limited processing capacity and memory are not adequate to process a full-chip, full-resolution image, requiring the user balance image size with resolution. This can be a problem when the STV is used with short-focus instruments. The STV can image much wider fields of view when attached to camera lenses of varying focal lengths and piggybacked on an equatorially mounted telescope. SBIG supplies c-mount adapters for the STV as well as adapters for Nikon, Olympus, Canon, and Pentax (bayonet) camera bodies. The STV's nosepiece attaches to the body of the CCD head with t-threads.

Deep-sky imaging with the STV is fairly straightforward once you figure out the tricks. Start by locating your target. The STV's small field of view can make this difficult, and a well-calibrated go-to telescope mount is desirable. Selecting a good exposure time will be pretty much a trial-and error process until you develop an intuition for how quickly the telescope and CCD collect photons under different Moon and transparency conditions.

The STV introduces new tools that help you get the most not only out of the CCD camera, but also out of your telescope and its mount.

The longer your exposure, the more electronic irregularities will begin to detract from your signal. The software allows you to correct for this automatically by applying a "dark frame" to your exposures. Dark frames are closed-shutter exposures that specifically measure electronic noise. To get the most out of your system, you should choose this option for your "keeper" images.

If your tracking drive isn't accurate enough to take long, unguided exposures without images trailing, you can operate the STV in "Track and Accumulate" mode. In this mode the STV takes and combines a series of short images (perhaps 30 seconds to a minute each) with a combined exposure time totaling that of a single properly exposed image. The downside of the "Track and Accumulate" mode is that co-added images may be noisier or have less resolution than a single guided exposure.

David Healy *fled New York eight years ago and has established a private observatory under the dark skies of southeastern Arizona. He is a frequent contributor of photos and equipment reviews to* Astronomy, *and has recently been named a contributing editor.*

The STV as autoguider

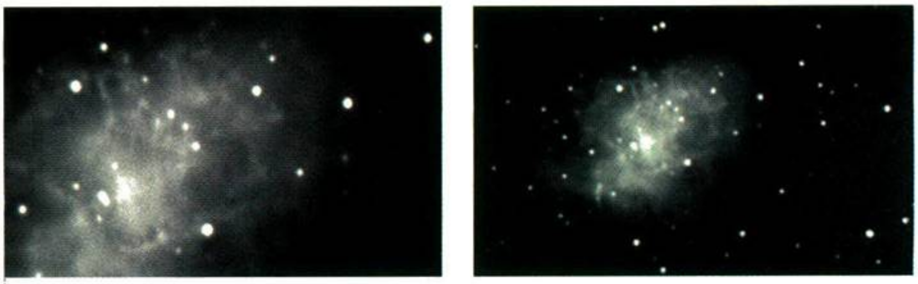
Setting up the STV as an autoguider is straightforward if you start out with the manual on your lap. The STV's RJ11 "Telescope" jack outputs autoguider data via a (supplied) telescope interface cable directly into the "CCD" port on many common telescope mounts such as the LX200, Ultima, and Losmandy. Other configurations also can be set up.

The 1¼" nosepiece of the STV's CCD head allows it to be mounted at a telescope's main eyepiece, in a guidescope's eyepiece holder, or it can be used with SBIG's eFinder. This ingenious accessory (a $495 option) combines a focal reducer lens with an extension tube that screws into the CCD head to produce a 1-inch aperture f/4 digital guidescope with a 2.7° by 2.0° field of view. This assembly can be attached via a mounting block tapped with a standard ¼—20 photo tripod socket. The eFinder can easily take the place of a larger aperture optical guidescope on shorter-focus telescopes. The STV is sensitive enough to detect guide stars in most regions of the sky with these setups.

In order to send proper guiding corrections to the telescope drives, the STV must be calibrated. If you have entered your telescope's correct aperture and focal length (including the focal reducer, if any) during the "Setup" routine, you may be able to instruct the unit to automatically select guide stars, test correction durations in four directions, and enter the resulting calibration into memory. If not, error messages such as "no motion" or "off screen" will oblige you to calibrate manually. The manual process is complicated, but an on-screen tutorial will help you tackle it step-by-step. Then you can center the object to be imaged, press the "Track" button twice, and you should be in business. If not, a manual "Track" menu allows you to enter proper tracking settings. The STV's "Interrupt" button is one of its most useful, since it allows you to start any process over.

Some exotic capabilities

The STV introduces new tools that allow you to get the most not only out of the CCD camera, but also out of your telescope and its mount. Three particular features stand out. The STV can measure the quality of your optical system by comparing it with a theoretically perfect system. It can also easily graph your drive's periodic error and declination drift at two different sampling rates, and it can measure atmospheric seeing by determining the full-width, half-max (FWHM) of point sources (e.g. stars).



SIDE-BY-SIDE IMAGES of the Crab Nebula taken in two imaging modes: zoom and wide. At full resolution (left; no binning), the STV reads out the inner 320x200 pixels. Binned 3x3, (right) the STV reads out the entire chip in "wide" mode. These images of the Crab Nebula were taken with the STV mounted on a 20-inch Ritchey-Chrétien telescope. DAVID HEALY

The STV also supplies two imaging modes that help you catch the one moment of good seeing on an otherwise terrible night. While in the "Large Mosaic" mode, to quote the STV's comprehensive operating manual: "The STV takes a series of six images, each cropped to the central 104x98 pixels and arranges the result in a mosaic of a single frame of two rows and three columns. . . . By automatically taking a series of exposures, your chances of capturing one or more during a moment of best seeing are increased." In the "Small Mosaic" mode the STV takes a series of 40 images, each cropped to the central 40x40 pixels, and arranges the result in a mosaic of five rows and eight columns.

The "Best Sharp" mode, to quote the manual again, divides the image screen in half, and "[t]he image on the left half of the video screen is updated continuously, but the image on the right half of the video frame is updated only when subsequent images are sharper . . ." This means that the STV can automatically select the best of an infinite series of images.

Evaluation

The STV seemed rather intimidating at first, with its buttons and knobs carrying such non-intuitive labels as "Parameter," "File Ops," and "Value." With practice and assistance from the detailed manual, however, it became familiar and easy to use — even intuitive. The same logic works in all modes of use.

Whether you want an STV for your observatory, backyard, astronomy club, or school depends on what you plan to do with the images it can produce or guide, and what level of imaging equipment you already have or aspire to. As an autoguider, the STV is state-of-the-art, at least for amateur astronomy. Its other capabilities, such as near-real-time video imaging and long-exposure CCD imaging, fall short of some of the dedicated instruments currently on the market. An observer interested only in video astronomy (someone limited to imaging from a light-polluted site, for example) might also consider the Astrovid line of cameras from Adirondack Video Astronomy. Someone interested solely in deep-sky imaging might also consider SBIG's dedicated CCD cameras — the ST-8, the ST-10, or the ST-2000. But for someone interested in getting his or her feet wet in astronomical imaging, the versatile STV makes an excellent first instrument. ■

The multi-purpose STV

chip: Texas Instruments TC237 antiblooming
pixel size: 7.4 microns
full frame: 656x480 pixels binned 4x4
full resolution: 320x200 pixels
exposure times: 0.001 to 600 seconds
readout time: 0.25 seconds in focus mode

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VIEWING TECHNIQUES

May offers an embarrassment of riches for skywatchers — not one, but *two* eclipses and a Mercury transit. Find out how to view this celestial trio. /// BY PHIL HARRINGTON

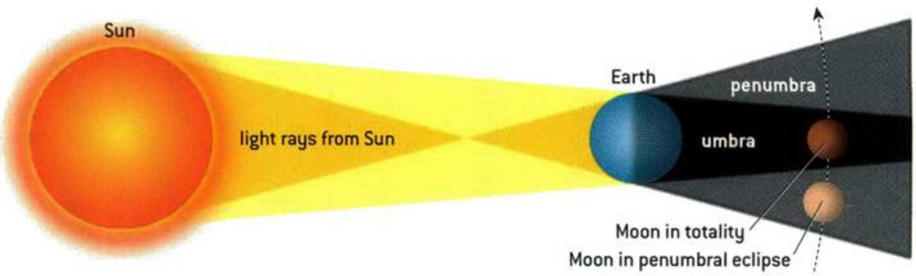
Eclipses and transits

This month, we have three chances to see our dynamic universe at work, thanks to both a solar and a lunar eclipse, as well as a transit of Mercury across the face of the Sun. Of these, the lunar eclipse on the night of May 15 will be the easiest to view. That's the nice thing about lunar eclipses — all you need are your eyes and a clear sky.

Beyond that, binoculars can enhance the contrast between the portion of the Moon covered by Earth's shadow and that untouched by it. A telescope also brings out some of the event's subtle nuances but is by no means a requirement.

Unlike most celestial objects, large apertures are not needed to view a lunar eclipse; in fact, the opposite is true. Telescopes greater than 8 inches (20 cm) in diameter make the Full Moon so overwhelmingly bright they muddle the distinction between Earth's lighter penumbra (where the Sun is only partially blocked) and darker umbra (where no direct sunlight hits). High magnifications also work against good views. Unless you are watching the shadow pass over specific lunar features, use your lowest power so the entire lunar disk fits into the field of view with room to spare.

Phil Harrington *is a contributing editor of* Astronomy *and the author of* Star Ware, *available at bookstores and on his website, www.philharrington.net.*



DARK SHADOWS of varying intensity fall across the face of the Moon depending on what fraction of the Sun is obscured by Earth. ROEN KELLY

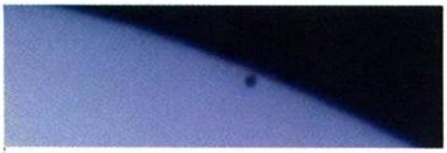
As the partial eclipse progresses toward totality, watch how the shadow seems to change color. During the early partial phases, it will probably look either dark brown, dark gray, or black, due to the contrast against the uneclipsed Moon. It never completely blackens, however, because light refracted by Earth's atmosphere will still reach it. As totality approaches, the color will shift to copper or reddish-brown — this is because blue wavelengths are scattered by the atmosphere. Variables such as the global clarity of the air and the relative position of the Moon and the center of Earth's umbra affect just how dark or colorful the shadow appears during totality.

It's always interesting to estimate the Moon's so-called luminosity value at various times during totality. To do this, astronomers use the Danjon scale, devised by the French astronomer André-Louis Danjon (see table below).

It is rare, though, for an eclipse to match one of these descriptions exactly. Most seem to fall somewhere between

/// DANJON LUNAR ECLIPSE LUMINOSITY SCALE

L = 0.0	Very dark eclipse; Moon almost invisible, especially at mid-totality.
L = 1.0	Dark eclipse, gray or brownish coloration; lunar-surface details distinguishable only with difficulty.
L = 2.0	Deep red or rust-colored eclipse; central part of the umbra dark, but outer rim of the umbra relatively bright.
L = 3.0	Brick-red eclipse, usually with a brighter (frequently yellow) rim to the umbra.
L = 4.0	Very bright copper-red or orange eclipse, with a bluish, very bright umbral rim.



TRANSITS OF MERCURY are notoriously difficult to observe, since the small planet's outline is virtually indistinguishable from a sunspot. This *1/60-second exposure* was taken November 15, 1999, using an 8-inch Schmidt-Cassegrain with a Baader AstroSolar filter. CHRIS COOK two values. Be sure to use only your eyes when estimating the brightness of the eclipse on the Danjon scale, since magnification often lessens the color's intensity.

Two weeks after the lunar eclipse, the Moon will step between the Sun and Earth to produce a solar eclipse for viewers in Greenland, Iceland, and parts of Alaska and Europe. To protect your eyes from harm, project its image onto a screen with a simple pinhole projector made from two pieces of cardboard. Punch a small hole, about the diameter of a pencil, in one of the pieces, and glue a sheet of white paper onto the other. When sunlight shines through the hole, a tiny image of the solar disk will be cast onto the paper.

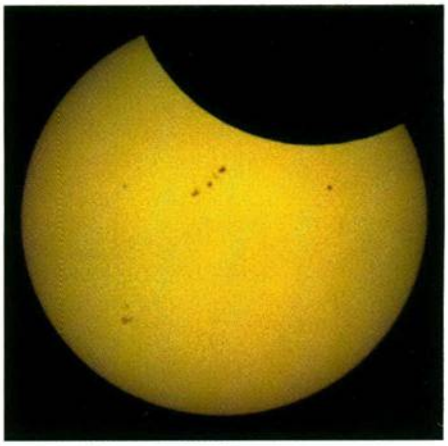
Six-inch and smaller telescopes are ideal for projecting the Sun's image onto a screen. But be careful not to look through the telescope or finder scope when aiming. Instead, move the instrument back and forth and up and down until the shadow it casts on the ground is at its shortest. The Sun should then be in, or at least near, the field of view. Move a piece of cardboard toward and away from the eyepiece to change the size of the projected Sun. Remember to turn the telescope away for 30 seconds every few minutes to prevent the intense heat from damaging its optics.

Many amateurs prefer viewing the Sun through solar filters, which fit over the front of telescopes and greatly sharpen images. Check the review of solar filters in the April 2001 issue of *Astronomy*, as well as online at Astronomy.com, for more information and consumer tips.

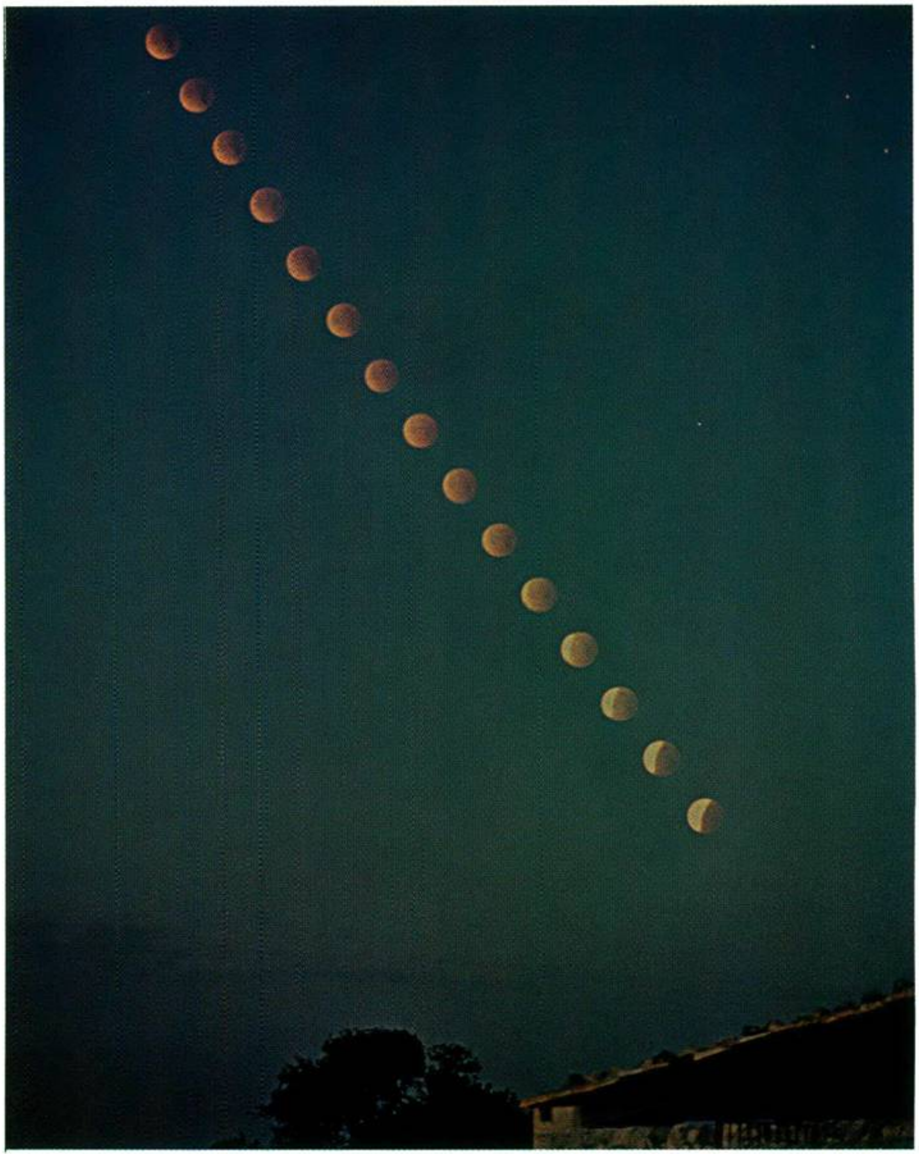
A telescope and solar filter are also best for watching the planet Mercury cross the Sun's face on May 7. You're still looking at the Sun, so follow the same precautions for viewing a solar eclipse. But in this case, because Mercury appears only $^{1}/_{194}$ as large as the Sun's diameter, try a telescope/eyepiece combination with a magnification of 50x to 100x. Make sure you're actually looking at Mercury — its perfectly round disk is easy to mistake for a small sunspot. Of course, sunspots don't move quite that quickly across the solar disk.

With a little planning, you can view all three of this month's events — a rare and wonderful opportunity brought about by a favorable alignment of the planets.

THE MOON blushes crimson when sunlight is blocked by Earth, whose atmosphere scatters blue light and refracts redder wavelengths that hit the lunar surface. CHRISTIAN VILADRICH



SOLAR ECLIPSES are best viewed on a screen or seen through a filter. This $^{1}/_{125}$-second exposure was taken through an 8-inch Meade LX10 fitted with a Baader AstroSolar filter at f/10. JESÚS OJEDA



LUNAR ECLIPSES are simple to view, as they require only your eyes and a clear sky. This series of four- and one-second exposures of the Moon (and the star Pollux, upper right) was taken with a Nikon 85mm at f/2 and f/8 from Sicily on January 21, 2000. GIANNI TUMINO AND MELANIA PLUCHINOTTA

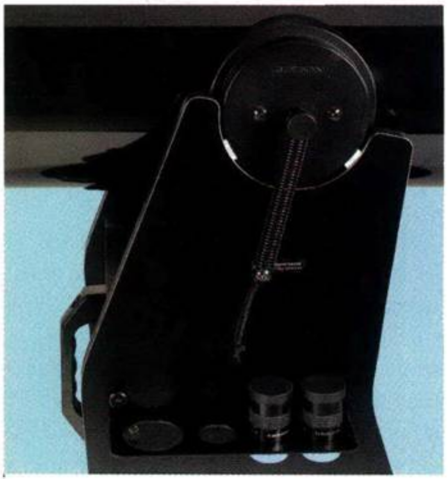
EQUIPMENT REVIEW

Orion's line of affordable Dobsonians brings a new level of joy to simple observing.

/// BY GLENN CHAPLE

SkyQuest: Easy exploring

In 1980, I purchased my first Dobsonian-mounted telescope — the Odyssey I from Coulter Optical Company. At the time, the Dobsonian revolution was still in its infancy, and Coulter was a pioneer in the market and sale of commercially-made Dobs. Although Coulter Optical Company is no longer in business, several reputable companies have continued the Dobsonian tradition. Among them is California-based Orion Telescopes and Binoculars. Modern-day Dobsonians are a vast improvement over the "bare-bones" versions produced back in the late 1970s and early 80s. How much of an improvement? I recently found out when I tested Orion's SkyQuest XT4.5, XT6, and XT8 telescopes. Much to my pleasure, these telescopes brought easy enjoyment to deep-sky exploration.



THE CORRECTENSION SPRING on SkyQuest Dobs prevents the telescope from slipping in altitude. The 8-inch model comes equipped with an eyepiece tray for three 1¼" eyepieces and one 2" eyepiece. The smaller scopes can hold three 1¼" eyepieces.

The assembly

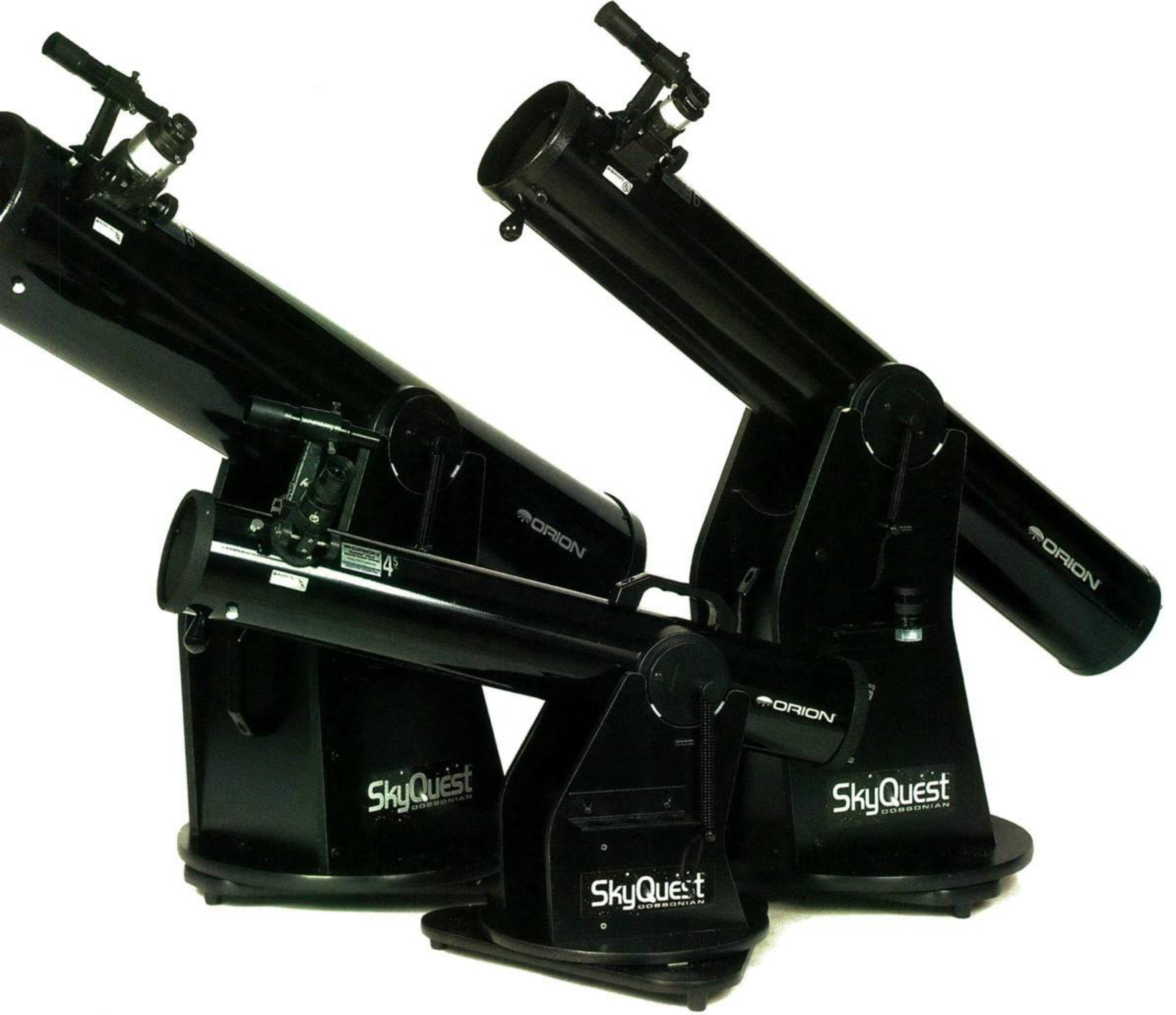
Each SkyQuest telescope ships in two boxes — one for the optical tube assembly and accessories, the other for the Dobsonian base. The optical tube arrives assembled (in fact, the mirrors in all three scopes were already collimated), while the base needs to be put together. Finishing touches on the telescope include installing the finder scope and connecting the optical tube assembly to the Dobsonian base with a tension spring. Because the XT4.5 is specially designed for a youthful beginner, I "farmed it out" to a father and son who had enrolled in an evening observational astronomy class I teach. With the class watching intently, they assembled the telescope in about 40 minutes using a few basic tools. At home, I tackled the XT6 and XT8. Working at a relaxed pace and carefully following the manuals' instructions, I was able to assemble each scope in well under an hour. The manuals — there is one for the XT4.5 and one for both the XT6 and 8 — are clearly written and illustrated. Sections include assembly, use, and care of the telescope and its various components, and a basic primer on recommended observing targets. The latter section was short and to the point.

Once assembled, the SkyQuest telescopes — their shiny black metal tubes perched atop sleek black Dobsonian mounts — were works of art.

Two specific features on the SkyQuest Dobsonian telescopes particularly impressed me. The first was the CorrecTension System, which connects the optical tube to the Dobsonian base with a spring. The altitude bearings on most Dobsonian-mounted telescopes tend to be loose. This causes the telescope to "auto-slew" toward the ground, particularly when pointed toward the horizon. The CorrecTension springs alleviate the problem by pressing the optical assembly firmly against the Dobsonian base, allowing for greater friction in the altitude bearings. With the CorrecTension springs engaged, a SkyQuest XT Dob holds steady, even with a heavy wide-field eyepiece in place.

The second Orion exclusive feature is the "navigation knob," located near the underside of the top of the tube. You can aim the scope with just one hand by grasping this knob and moving the scope. This provides extra leverage and gripping power. The navigation knob is useful for pointing the SkyQuest Dob at targets up to about 70° above the horizon. For objects located near the zenith, you'll need to support the scope with both hands. The whole unit tends to tip if you try maneuvering it with just the navigation knob.

> I had no trouble transporting the 8-inch and was amazed at how a scope of this aperture handled with small-scope ease.



THE SKYQUEST FAMILY OF DOBSONIAN TELESCOPES comes in a variety of sizes. Starting with a 4.5-inch scope designed for children, through the standard 6-inch and 8-inch models, they reach all the way up to a 10-inch scope (not shown) that can bring deep-sky mysteries into focus.

ALL PHOTOS JAMES FORBES

The SkyQuest Dobs are extremely portable. With the CorrecTension spring in place the XT4.5 can be toted around simply by picking it up with a handle located on the main tube. The XT6 and XT8 can be picked up by a handle on their bases. The XT4.5 is light enough to be handled by virtually anyone, while the XT6 and 8 might be a bit too hefty for some individuals. One can also unhinge the tension springs and carry the scope in two pieces. I had no trouble transporting the 8-inch and was amazed at how a scope of this aperture — a true giant back in the pre-Dobsonian era — handled with small-scope ease.

Setup

A drawback with reflecting telescopes is the need to collimate (align) the optics — a task that discourages many beginners. As noted earlier, the SkyQuest Dobs I reviewed were already collimated. Should collimation be necessary, the manual provides a clear, well-illustrated description of the process. The mirror cells on the SkyQuest telescopes have three thumbscrews that lock and unlock the mirror, plus three that align the mirror. The process is eased by a provided collimation cap that fits over the focuser drawtube/eyepiece holder and a center mark on the main mirror.

Orion's finder scope is another plus for this next-generation Dobsonian. For years, a stable finder had to be mounted with two brackets. Aligning the finder scope with the telescope required trial-and-error turning of six thumbscrews (three per bracket). I was skeptical when I first saw a SkyQuest finder scope in its one-bracket holder — a configuration reminiscent of the rickety one-bracket finders that used to be found on cheap department-store telescopes. To my surprise, the Orion's one-bracket finder was quite stable and aligned easily with the main scope using just two thumbscrews. The SkyQuest XT4.5 finder scope dif-

ORION SKYQUEST DOBSONIANS	XT4.5	XT6	XT8
APERTURE	114mm	150mm	203mm
FOCAL LENGTH	900mm	1200mm	1200mm
FOCAL RATIO	f/7.9	f/8	f/5.9
FOCUSER	rack & pinion	rack & pinion	rack & pinion
EYEPIECES	25mm Plössl 10mm Plössl	25mm Plössl 10mm Plössl	25mm Plössl 10mm Plössl
EYEPIECE HEIGHT	34"	46"	46"
FINDER SCOPE	6x28 rectified achromatic finder	6x30 rectified achromatic finder	6x30 rectified achromatic finder
DIAMETER OF SECONDARY	28mm	34.5mm	47mm
WEIGHT	17.6 lbs	38.4 lbs	42.6 lbs
COST	$199	$329	$449

fers from the finders on the XT6 and 8 in that it produces an upright, or rectified, image. This is helpful for the beginner who might be confused trying to aim his/her scope using the standard inverted-image finder.

Temperature differences between the air and optics can create image noise that is rooted in the same thermodynamics that create highway mirages. A telescope taken outside requires a certain "cool-down" time, as the telescope acclimates to the outside temperature. All things being equal, the larger a telescope is, the longer the cool-down period. The mirror cell of the XT8 is open to the air to expedite its cooling by allowing greater air flow around the mirror. Orion even offers an inexpensive battery-powered fan that attaches to the mirror mount. I avoided the need for telescope cool-down simply by leaving the SkyQuest Dobs secured on an open back porch, where they would stay acclimated to the outside temperature.

All three SkyQuest scopes come with standard 1¼" Sirius Plössl eyepieces in 25mm and 10mm focal lengths. While not "top of the line," they produce very clear images, offer comfortable eye relief, and are parfocal (when you switch eyepieces, you don't have to do a lot of refocusing). The XT4.5 and 6 use 1¼" eyepieces exclusively, and each Dobsonian base has a holder with space for three eyepieces. The XT8 can utilize either 1¼" or 2" eyepieces, and its eyepiece rack can hold three 1¼" eyepieces and one 2" eyepiece. A word of caution: When placing a 1¼" eyepiece in the eyepiece rack of the XT8 on a dark evening, be sure you're not accidentally placing it in the 2" slot. Your eyepiece will drop through the slot onto the ground (I learned the hard way!).

Viewing

Are the SkyQuest XT Dobs as nice to look through as they are to look at? The XT4.5 got "two thumbs up" from the father-son team that tried it out. They cited its ease of operation and were impressed by the spectacular "outer space" views it revealed. Their only complaint (and a mild one, at that) came from Dad, who said the eyepiece tended to be a bit low for him. I found it nearly impossible to look through the finder scope when pointed near the zenith. Orion acknowledges this shortcoming, and advises adults either to use the XT4.5 while seated in a lawn chair or after elevating the scope on a table or solid crate.

Although the XT4.5 was especially designed for the young astronomer, this is not a child's toy. In the hands of an experienced skygazer, this little Dob can "dig deep." I used it to make some variable star observations and was able to see stars as faint as 13th magnitude.

I can sum up my experiences using the SkyQuest XT6 and 8 scopes in one word — fun! The mount and focuser were solid, yet smooth as silk, making operation of these scopes a pleasure. If I tapped

FULLY EQUIPPED, the XT8 Dob has a navigation knob to aid in pointing, a 6x30 achromatic finder, and an eyepiece assembly that supports 1¼" and 2" eyepieces.

WARNING
ORION
SkyQuest XT8
8

Glenn Chaple *teaches science in the Groton-Dunstable school system in Massachusetts. He has observed the sky for more than 30 years.*

DESIGNED FOR CHILDREN, the eyepiece on the XT4.5 will be too low for many adults to comfortably access. Putting the scope on a solid box or table can solve this problem.

AN EXCELLENT ENTRY LEVEL SCOPE, the XT6 is light enough for most people to carry. It's also so easy to aim at celestial targets that you won't miss go-to technology.

SERIOUS OBSERVING POWER can be found in the XT8. For the deep-sky observer, this powerful scope is the way to go. Its built-in eyepiece tray holds four eyepieces.

the tube, the image settled down in a matter of seconds. Because the XT6 and XT8 have identical focal lengths, the views through each were comparable. Both scopes performed well on a variety of sky objects — from the Moon and planets, to double stars, to deep-space objects. Saturn was a grand sight. The Cassini division was visible even under poor seeing conditions. Epsilon Lyrae, the famous "Double-Double," was beautifully resolved with star images that rivaled those I normally expect from refracting telescopes. The Double Cluster in Perseus, as well as the Pleiades, was especially eye-pleasing. Star images were crisp throughout most of the field of view, although there was a slight coma at the very edge of the field. The Veil Nebula, though faint, was distinctly visible with no need for special filters.

I brought the XT8 to a local star party in place of my regular Odyssey I. The XT8 traveled well, set up in less than a minute, and provided crowd-pleasing views of Saturn, the Moon, and the Orion Nebula. Several of the people in attendance tried out the scope and marveled at its ease of operation.

I always like to field-test a telescope by using it to do some "serious" work. With the XT6 and 8 SkyQuests, I made observing runs on eclipsing variable stars. The typical eclipsing variable requires that a brightness estimate be made every ten minutes for a 3-hour to 5-hour period around the time of predicted eclipse. Because the SkyQuest Dobs aren't motorized and cannot track a sky object, the eclipsing variable being monitored had to be relocated and centered in the eyepiece field during each observation. The XT6 and 8 operate so smoothly that relocating the target star was never a problem. I managed several successful observing runs.

What's right for you?

My recommendations for the suitability of the SkyQuest Dobs pretty much mirror Orion's. The XT4.5 is an ideal beginner's scope for the youthful astronomer, while the XT6 might serve as an excellent entry-level telescope for an adult. The XT8, of course, is the way to go for serious amateurs interested in visually observing the sky. Orion also offers a SkyQuest XT10, which I didn't test. Basically, it's an upgrade of the XT8, complete with Pyrex mirror (the other SkyQuests use plate glass mirrors) and a 9x50 finder scope.

Considering the features the SkyQuest Dobs offer, their retail prices are quite reasonable. Add the fact that each SkyQuest telescope comes with "The Sky" CD-ROM, and you have a true bargain. The father-son duo who tested the XT4.5 raved about "The Sky," which, among other things, produces on-demand star charts and contains thousands of interesting color and black-and-white space images.

The Dobsonian revolution has come a long way since those promising beginnings some three decades ago. The once-clunky Dobs have evolved into sleek optical machines. Whether you're a beginner looking for a quality, easy-to-use telescope at a reasonable price, or a veteran skygazer seeking a telescope that can do serious work (again, at a reasonable price), you need to give the Orion SkyQuest Dobs a look. ■

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EQUIPMENT ROUNDUP

Giant binoculars reveal a universe of detail by fully utilizing the factory-installed human optical system. /// BY PHIL HARRINGTON

High-power twin optics

When it comes to viewing the night sky, two eyes are better than one. Research shows that using both eyes can greatly improve our perception of faint objects, especially with nebulous targets. When the brain receives two separate, but nearly identical, signals from both eyes, it is able to process out interferences, such as floaters and other visual "noise" along the eye-to-brain link. The result: a better view of the universe.

In this review, three popular giants — the Kowa 32x82 High Lander Prominar, Miyauchi 20x100 Bj-100iBF, and Oberwerk 25/40x100 Military Observation Binoculars — are compared side by side for image clarity, contrast, and sharpness. Each is built around pairs of Porro prisms that take the light entering through the objective lenses and bounce it around into the eyepieces, flipping the image right side-up in the process. Each has prisms made from premium quality BaK-4 glass.

Overcoming visual noise

Many advanced observers connect binocular eyepiece holders to their telescopes. These split the incoming light into two paths, directing it toward a pair of identical eyepieces, which allows observers to use both eyes. Unfortunately, every lens that light passes through, and every reflection it makes, scatters some light. Binocular viewers not only introduce an additional reflection, but they also split the incoming light, halving the amount of light reaching each eye. This is the same as reducing a telescope's aperture by the square root of 2. Instantly, an 8-inch telescope acts like a 5.6-inch telescope. While binocular viewers work well on bright objects, such as the Moon and planets, the splitting extracts a heavy cost on dimmer objects. Depending on their design, binocular viewers can lose as much as a full magnitude of light (although this is partially offset by using both eyes), lowering their usefulness on faint targets.

Many dyed-in-the-wool binocularists use giant binoculars, usually ranging between 60mm and 80mm (2.5-inch and 3.33-inch) in aperture and magnifying between 11x and 30x. For binocular connoisseurs who want true two-eyed viewing, but who crave even larger apertures and higher magnifications, several companies have introduced some truly enormous binoculars. Measuring between 82mm and 150mm in aperture and magnifying 20x or more, these monster binoculars are more akin to amateur telescopes than to the smaller binoculars we might use at a moment's notice to check on the night sky or to identify a bird in the backyard. There's no slinging these over the shoulder for a quick night out!

The Kowa High Lander 32x82

A well-known name in the spotting-scope industry, Kowa also markets a number of binoculars, including the distinctive 32x82 High Lander Prominar binoculars reviewed here. Their silver barrels feature a built-in carrying handle and removable eyepieces that are tilted 45° to make sky viewing easier. Each dry-nitrogen-filled barrel has a threaded dust cap and an extendable dew shield that slides out in front of the objective lens. Kowa High Landers are available with either achromatic objective lenses or multi-element apochromatic objective lenses highlighted by a fluorite element, which eliminates false color completely, even under the most demanding conditions. Both binocular styles include fully multicoated optics.

The High Lander Prominars come standard with a pair of wide-field 14mm eyepieces, yielding 32x in these f/5.48 instruments. The individually focused eyepieces, a Kowa-proprietary optical design, have 16.5mm of eye relief and a wonderful 70° apparent field of view — the widest in this group. This combination yields a true field of view of 2.2°, which is perfect for viewing many deep-sky objects. Looking for a little more magnification? Kowa's eyepieces can be swapped easily for an optional pair of 9mm eyepieces to raise the magnification to 50x. Although the Kowa eyepieces have 1¼-inch barrels, they are specially designed to plug securely into the eyepiece holders. Unfortunately, they are not threaded to accept filters. Standard 1 ¼-inch eyepieces also fit, but cannot be locked in place. As a result, they could easily fall out of the eyepiece holders when the binoculars are tilted skyward.

High Landers are much too heavy to be supported by anything but a sturdy tripod (sold separately by Kowa), or a heavy-duty parallelogram mount, like those from Universal Astronomics.

Miyauchi Bj-100iBF 20x100

The 20x100 Miyauchi Bj-100iBF, imported into the United States by

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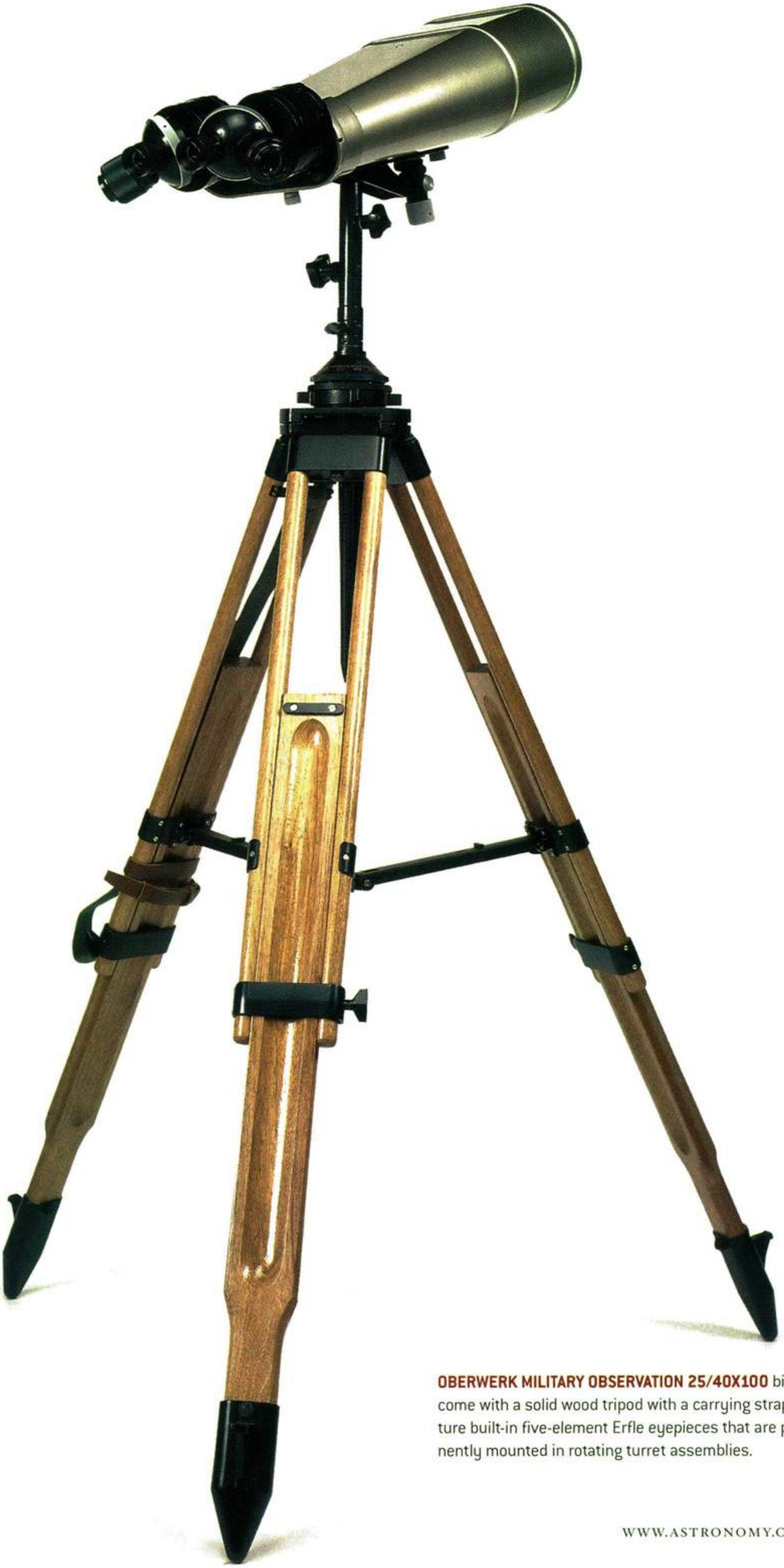
Phil Harrington *has been viewing the sky with binoculars for more than three decades. His book* Touring the Universe Through Binoculars *is available at bookstores as well as through his website, http://www.philharrington.net.*



OBERWERK MILITARY OBSERVATION 25/40X100 binoculars come with a solid wood tripod with a carrying strap and feature built-in five-element Erfle eyepieces that are permanently mounted in rotating turret assemblies.

PROMINAR
Kowa
HIGH LANDER

KOWA HIGH LANDER PROMINAR binoculars have a 70° apparent field of view that is unmatched in this class of binoculars. The actual field of view is 2.2° at 32x.

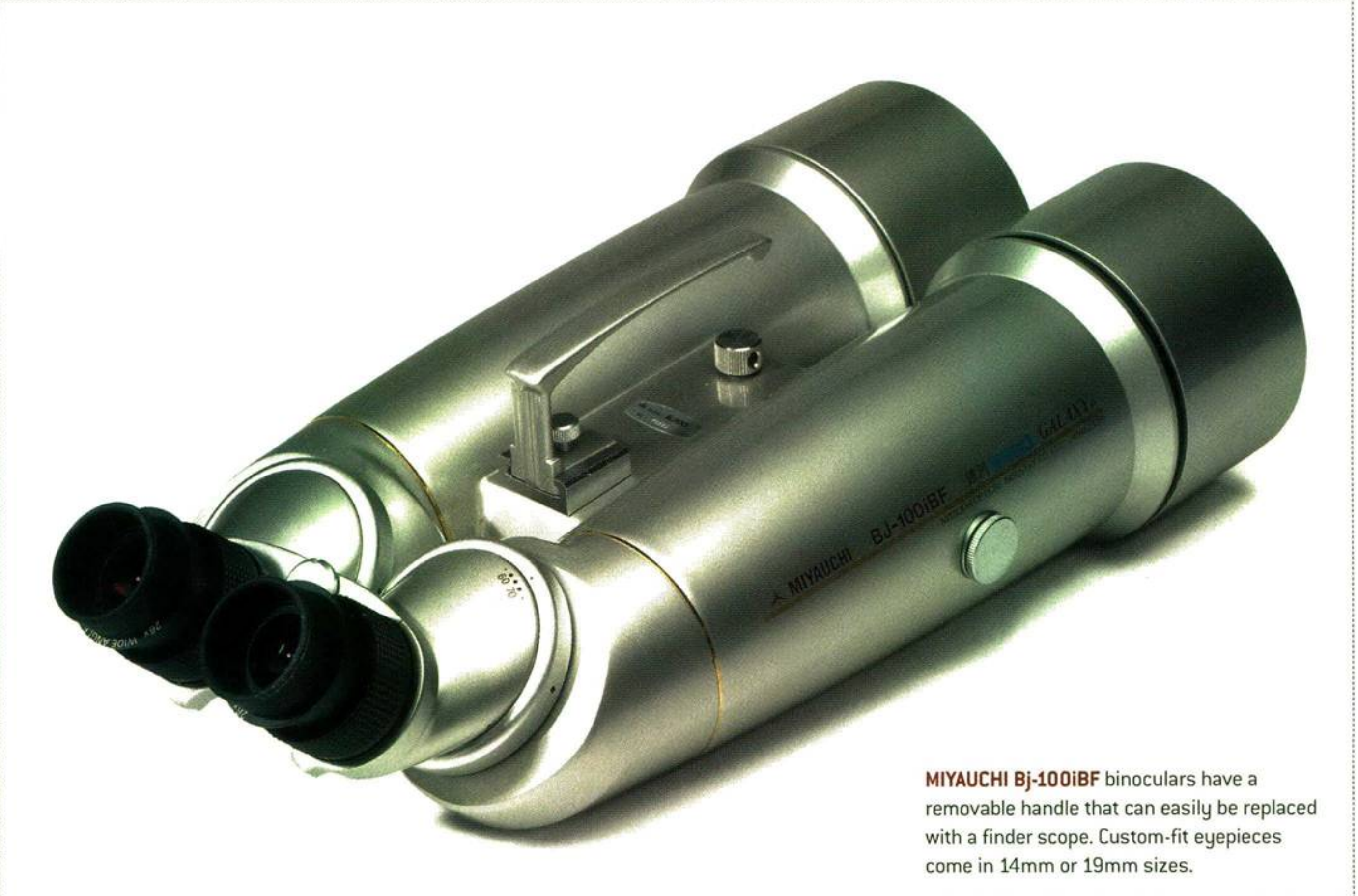
Land, Sea and Sky in Houston, also have fully multicoated fluorite apochromatic objective lenses for excellent false-color suppression. Each of the 100mm f/5 objective lenses consists of five elements set in two groups. Like the Prominars, the Miyauchi's nitrogen-filled aluminum bodies have a distinctive silver-colored finish that sets them apart from most binoculars. They also include a carrying handle attached to a bracket on the binoculars' central bridge. Unlike the Kowas, whose handle is integrated into the barrel design, the Miyauchi handle can be removed and replaced with an optional 3x finder scope. The Miyauchis tested here did not include the finder, but I have used one in the past and found it to be a very handy aid.

With an apparent field of view of 50°, the individually focused 20x Miyauchi eyepieces create a true field of view of 2.5°. These eyepieces can be replaced with either 14mm or 19mm custom-fit eyepieces for 37x and 26x magnification respectively, and each has a generous 66° apparent field of view. Although Miyauchi eyepieces have 1¼-inch barrels, they are specially designed to plug snugly into the binoculars. Again, like the Kowas, they are not threaded to accept filters. There is also no provision for securing non-Miyauchi eyepieces. Like Kowa, Miyauchi tilts their eyepieces at 45°, which goes a long way to easing back and neck distress, especially when looking far above the horizon.

Oberwerk Military Observation 25/40x100

Finally, Oberwerk Military Binoculars come standard with two sets of five-element Erfle eyepieces that are permanently mounted in two rotating turret assemblies. One eyepiece pair magnifies 25x, the

MODEL	MAGNIFICATION	APERTURE	EXIT PUPIL	EYE RELIEF	FIELD OF VIEW	WEIGHT	TYPICAL COST	CONTACT INFORMATION
Kowa High Lander Prominar	32x	82mm	2.6mm	16.5mm	2.2°	14	$4,000	Kowa Optimed, Inc. 20001 S. Vermont Ave. Torrance, CA 90502 [t] 800.966.5692, 310.327.1913
Miyauchi Bj-100iBF	20x	100mm	5mm	25mm	2.5°	14	$3,900	Miyauchi (c/o Land, Sea & Sky) 3110 South Sheperd Houston, TX 77098 [t] 713.529.3551 www.lsstnr.com
Oberwerk 25/40x100 Military Observation Binoculars	25x & 40x	100mm	25x: 4mm 40x: 2.5mm	25x: 14mm 40x: 8.2mm	25x: 2.5° 40x: 1.5°	26	$1,400	Oberwerk Corporation 2440 Wildwood Xenia, OH 45385 [t] 866.244.2460, 937.372.5409 www.bigbinoculars.com



MIYAUCHI Bj-100iBF binoculars have a removable handle that can easily be replaced with a finder scope. Custom-fit eyepieces come in 14mm or 19mm sizes.

other 40x, and since the eyepieces focus individually, there is no need to refocus when switching magnifications.

The Oberwerk features three-element objectives for better color correction than traditional two-element achromats. They are also multicoated to suppress flare and improve light transmission.

The Oberwerk Military Binoculars are also unique for their single, oval barrel, which helps prevent them from sagging under their own weight (a whopping 26 pounds). A center mounting post matches the binoculars to the included all-wood field tripod. The tripod extends to a height of 60 inches (1.4 meters) and weighs 16 pounds. A permanently attached shoulder strap makes carrying the tripod easy. The binoculars come in a padded, suitcase-style carrying case that will protect them for years to come.

Head-to-head comparisons

Each of the binoculars was delivered in perfect condition. An initial inspection showed that alignment was dead-on, and the inside of each was free of dust, metal shavings, and other impurities that can become sealed in during manufacture. Each objective lens and eyepiece showed even coatings that were free of imperfections and blemishes.

Daytime tests of each pair were conducted by aiming the binoculars toward a distant picket fence, since the fence's horizontal and vertical members created very good reference planes for checking curvature of field, astigmatism, and distortion (see "Two eyes on the sky," *Astronomy*, April 2003). Field curvature was nonexistent in either the Kowas or Miyauchis and barely noticeable in the Oberwerks. None showed any signs of astigmatism, which is usually associated with poorly made or poorly collimated optics, or improper manufacturing.

The Kowa High Lander Prominars possess some of the finest binocular optics I have ever looked through. They gave no hint of distortion, producing a textbook-perfect flat field. Views were sharp and demonstrated excellent contrast. There was no sign of the purplish or yellowish tinge that would indicate residual chromatic aberration.

Distortion was only slightly evident along the very outer edge of the field of view in the Miyauchis. They also showed a slightly yellowish edge along the sunlit fence, indicating some false color despite the apochromatic objectives.

Lastly, the Oberwerk's distortion was evident across the outer third of the field, causing the fence pickets to appear

> Each of these giant binoculars offers an amazing visual experience that can never be equaled through a one-eyed telescope.

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MODEL	RESOLUTION	BRIGHTNESS	CONTRAST	SHARPNESS	VIEWING COMFORT
Kowa High Lander Prominar	☾☾☾☾☾	☾☾☾☾	☾☾☾☾☾	☾☾☾☾☾	☾☾☾☾
Miyauchi 20x100 Bj-100iBF	☾☾☾☾☾	☾☾☾☾☾	☾☾☾☾	☾☾☾☾	☾☾☾☾
Oberwerk 25/40x100 Military Observation Binoculars	☾☾☾☾	☾☾☾☾☾	☾☾☾☾	☾☾☾	☾☾☾

☾☾☾☾☾ exceptional; ☾☾☾☾ very good; ☾☾☾ good; ☾☾ fair; ☾ poor

bowed or warped. The edges of the fence rails were also falsely colored with a yellowish tint.

Under a dark sky, the binoculars' true astronomical worth shone through. The large apertures and high magnifications were perfect for picking out specific deep-sky targets, yet their fields of view were still much wider than most telescopes, making them ideal for viewing large star clusters and nebulae.

Of all the binoculars in this group, the Kowa High Lander Prominars impressed me the most. Despite (or perhaps because of) the comparatively small exit pupil of only 2.6mm, their image contrast and brightness were exceptional. Thanks to the apochromatic objective lenses, there was no sign of false color even when viewing the Moon and bright stars, like Vega. Star images were pinpoint sharp with exceptional contrast. The Pleiades, the Double Cluster, and the star clouds through central Cygnus were breathtaking, each sparkling like diamonds. Thanks to Kowa's 45° angled-eyepieces, viewing was easy even when the binoculars were tilted high in the sky.

The Miyauchis were also outstanding performers. Image contrast and sharpness were every bit as good as the Kowas. At the same time, their extra-large aperture added just enough punch to bring out subtle details that were missed in the smaller Kowas, such as two dark lanes along the plane of M31 and several diffuse patches within nearby M33. The Miyauchis, however, showed hints of purple and yellow around the Moon, Sirius, and Vega, whereas the Kowas showed none. Keep in mind, however, that these are unforgiving tests; chromatic aberration was completely undetectable around other fainter sky objects.

If I could give a "bang for the buck" award, it would go to the Oberwerk Military Binoculars. For less than half the cost of the other units, you get a pair of 4-inch refractors outfitted with turret eyepieces and a custom tripod and mount. But all that would be of little value if the binoculars themselves didn't deliver. I found the images through these monsters to be sharp, with excellent contrast and resolution. Their large aperture allowed me to view 12th-magnitude stars from a local dark-sky site.

My only complaints about the Oberwerk giants involve their mount, not the binoculars themselves. First, the supplied tripod was too short for me and my 6′4″ frame to comfortably view objects that were above an elevation of about 45°. If this concerns you, consider a second style of Oberwerk's 100mm binoculars that come outfitted with eyepieces tilted at 45°. Although they do not have dual eyepieces, and cost about $200 more, you will easily save that money in chiropractic bills.

Another problem shared by both of Oberwerk's 100mm models is that the binoculars' mounts limit their tilt to no more than about 70° above the horizon. I couldn't get the binoculars any closer to the zenith without the bottom of their barrels hitting the mount. Of course, given the straight-through eyepieces and height of the tripod, viewing near the zenith would have been very difficult regardless of the tripod.

A few words in parting

Each of these giant binoculars offers an amazing visual experience that can never be equaled through a one-eyed telescope. Their large apertures coupled with superb optics make them a great ticket to the universe. These instruments are heavy-duty in their physical dimensions and in their optical abilities. While not practical for a quick peek at a passing satellite, they are more than capable of taking you on a tour of the heavens when mounted on a tripod or heavy-duty parallelogram mount. ■

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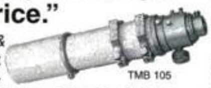
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Renaissance 102, 4" f/8.6 brass apo	2935^{00}
TV-85, 3.35" f/7 apo	2080^{00}
TV-76, 3" f/6.3 apo	1675^{00}
Pronto, 2.7" f/6.8 semi-apo	1120^{00}
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NP-127
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$579

Some observers enjoy hunting for celestial objects the way the pioneering astronomers did – by eye, star hopping from object to object. Others want a go-to scope to do the hunting for them, but have a budget that says, "Can't afford a go-to yet." For both groups, the Meade LXD55 EC scopes are the upgradeable answer!

The 5" EC multicoated achromatic refractor and fast focal ratio Schmidt-Newtonian 6" and 8" reflectors (with either standard optical coatings or optional UHTC optics) are complete working scopes, with dual-axis DC drives and a four-speed/four direction EC hand control (both of which are costly options with competitive scopes). You can star hop or use setting circles to find objects. Once found, the scopes track those objects automatically while you observe at your leisure.

For the observing purist or the observer on a budget, a Meade LXD55 EC model is all the scope you need. *But* . . . if you add an optional Autostar computer later, you'll have a fully computerized go-to telescope with a memory of 30,000 stars and objects. You have as much or as little automation as you want, at a price you can afford *now!*

$699
Meade 8" SN-8EC f/4 reflector
(\$824 w/UHTC)

Vixen products available from stock.

For years, high quality Vixen telescopes and accessories from Japan have been best-sellers in Europe. Now, Vixen is also available in the U. S. – imported by TeleVue, a company with a sterling reputation for quality of its own.

Whether it's a telescope, a German equatorial mount, or a visual or photographic accessory, if it's from Vixen, chances are good we have it in stock. All the Vixen Lanthanum long eye relief and wide angle long eye relief eyepieces are ready to ship. Also in stock are the well-known and standard-setting Great Polaris and Great Polaris DX mounts to use with your own optics. If you want optics that are out of the ordinary, we have Vixen's ED glass, fluorite, and dual ED doublet apo refractor optical tubes and complete telescopes. If it's a Vixen, it's probably in our stock right now. Check our website for a complete listing of available items or call us at (800) 422-7876 to see for yourself.

$2200
Vixen GP ED102S
4" f/9 ED apochromatic refractor
(shown with optional motor drive)

> I bought my first Orange Tube C-8 from Astronomics in 1981 and have been a repeat customer many times since, so I did not hesitate to order my new Celestron NX-11GPS from you. I can't believe I placed the order on a Sunday afternoon and it was delivered on Thursday of the same week. How can you beat a deal like that?
>
> **Customer Quote of the Month #134**

A whole lot less shaking going on!

Sky & Telescope said that hand-holding Canon image-stabilized binoculars was "truly a quantum leap in binocular observing." Canon's electro-mechanically stabilized terrestrial and astronomical images are rock-solid, not jittery and blurred, no matter how unsteady your hands. You'll simply see more detail than you can with conventional binos. There are big 15 x 50mm and 18 x 50mm models that are excellent for astronomy. Full details are on our website.

Over 1,000,000 people a year visit our website for reliable info, helpful features, and secure on-line shopping.

www.astronomics.com

Our *five* brands of light pollution filters bring dark skies to your light-polluted world.

If city lights are blocking your view of the heavens, you can get rid of that interference with one of the many light pollution filters we stock. They often make the difference between seeing nebulas and galaxies from cities and suburbs and missing them completely.

We carry the **Celestron** broadband filter in a 1.25" version for eyepieces and a version that threads onto Schmidt-Cassegrain rear cells.

We carry all **Meade** broadband, narrowband, and Oxygen III filters in both 1.25" eyepiece versions and rear cell versions for Schmidt-Cassegrain use.

We carry **Sirius** 1.25" and 2" broadband filters – nebula, Oxygen III, H-Beta, planetary contrast enhancement filters, and Neodymium planetary contrast filters for eyepiece use; their variable filter system; and their IR and UV photographic filters.

The newest additions to our light pollution filter family are the 1.25" and 2" **TeleVue** UHC and Oxygen III eyepiece filters.

Last but not least, we carry the **Thousand Oaks** broadband, narrowband, Oxygen III, and H-Beta filters in both 1.25" and 2" versions for eyepiece use.

Our free catalog helps you pick the right Celestron, Meade, Questar, Stellarvue, Takahashi, TeleVue, TMB, or Vixen scope.

For the most detailed and fully illustrated information on individual products, visit our web site at **www.astronomics.com**. If you'd prefer, call us at (405) 364-0858, or send an e-mail, for your *free* copy of our catalog AST.

It includes our 8-page guide on how to pick the right scope, plus your discount prices on the 1500+ products we carry – from Antares, Astrozap, Canon, Celestron, Coronado, Discovery Telescopes, Fujinon, JMI, Leica, Losmandy, Meade, Minox, Miyauchi, Nikon, Parallax, Pentax, Questar, Rigel Systems, SBIG, Sirius Optics, Sky Publishing, Software Bisque, Starbound, Starlight Instruments, Stellarvue, Swarovski, Swift, Takahashi, TeleVue, Thousand Oaks, TMB, Vernonscope, Vixen, Zeiss, and more. (Sorry, U. S. sales only.)

The catalog is yours for only the cost of a one minute phone call. The information and pricing we send will make it the most useful minute you'll ever invest in astronomy. Prices in this ad are current as of 2/5/03, but subject to change.

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Why wait? We'll ship your Meade LX90 from stock . . . and save you $200!

Meade 8" LX90
$1495
thru 4/30

Meade prices are about the same anywhere you call. So why order a Meade scope or accessory from a dealer who charges your credit card, then makes you wait and wait until he finally gets around to ordering what you want? Not when you can usually get the Meade telescope you want from stock . . . right now . . . at the right price . . . right here at ***astronomics.***

The **Meade LX90** lets you enjoy go-to astronomy for not a lot of money. The 8" LX90 with standard optical coatings is sale priced at only $1495 through 4/30. UHTC (Ultra High Transmission Coatings) optics provide up to 20% brighter images for only $175 additional. Both versions come with a heavy-duty adjustable height tripod, Autostar computer with 30,223 star and object memory, 8 x 50mm finder, and 26mm Super Plössl eyepiece.

We usually have the LX90 in stock at all times (both standard and UHTC versions), so you can probably get *your* LX90 with little or no delay. If Meade is shipping the LX90 *(or any Meade telescope)* for a dealer to keep in stock, the chances are very good we *have* it in stock.

7" to 10" Meade GPS UHTC scopes ship from stock. And you save $500 on each through 4/30!

Meade 8" LX200 GPS
$1995
thru 4/30

Meade LX200GPS telescopes have all the features you've dreamed about since you started astronomy – plus optional UHTC (Ultra High Transmission Coatings) optics that give you up to 20% higher light transmission so you can see 20% more of the Universe.

And, through 4/30, each is sale-priced $500 below its regular price. The 8" LX200 GPS with standard coatings is on sale for only $1995!

Meade's *fully automatic* GPS (Global Positioning Satellite) alignment system, with its true north and true level sensors and automatic magnetic declination correction, takes the time and guesswork out of setting up your scope. You'll be observing in mere minutes. The built-in computer, with a database of over 145,000 stars and objects, will find deep space and solar system objects for you *automatically*. You'll spend more of your time looking *at* heavenly bodies and less time looking *for* them.

We keep Meade LX200GPS scopes in stock. Chances are good we have one ready to ship to you.

Get a free Autostar hand control and deluxe field tripod when you buy a Meade ETX.

Authorized Meade Dealer

Through May 31st, you'll get a *free* Meade #497 Autostar computer hand control and #884 deluxe field tripod when you buy any ETX Maksutov-Cassegrain. The Autostar and #884 tripod normally retail for $348.95, but they're *free* when you buy any ETX-90, 105, or 125 through 5/31!

And, through 4/30, the purchase of any ETX Maksutov still entitles you to get $650 worth of Meade Super Plössl eyepieces for only $99!

The 3.5" **ETX-90EC** costs only $495 plus freight ($50 additional for UHTC optics). The 4" **ETX-105EC** is $695 plus freight ($75 for UHTC optics). And the 5" **ETX-125EC** is $895 plus freight ($90 for UHTC optics).

Buy any of them, even the least expensive, and you get $348.95 of accessories for free! Even better, for only $99 you can get eyepieces worth $650 direct from Meade!

The Stellarvue refractor is a "hot new product."

AT1010 **$499**
shown w/optional diagonal and eyepiece

The 80mm f/6 **Stellarvue AT1010** refractor was named a "Hot New Product" by *Sky & Telescope*. Independent reviews say this achromat competes favorably with semi-apo ED scopes that cost twice its modest price, and that it easily outperforms imported achromats in color correction and resolution. The AT1010 has triple tested hand-assembled optics, tube rings, a tripod adapter, a 2" focuser with 1.25" adapter and T-threads, red dot finder, oversize rubber-grip focus knobs for easier use in cold weather, and a soft padded carry case. It's a super deal that's ready to ship now. We keep many Stellarvue refractors in stock, from 78mm to 102mm, *including APOs.*

Sell your used telescopes and accessories quickly for free by using the no-charge classified ads at www.astrofieds.com

Multicoated optics? They're standard on the NexStar 8 GPS.

NexStar 8 GPS
$2499

Celestron's 8" **NexStar 8 GPS** Schmidt-Cassegrain has all the features that you expect from a GPS scope, including *standard equipment* Starbright high transmission multicoated optics for brighter images.

It also has some unique features unavailable in other GPS scopes. For example, you can convert its unique Fastar f/10 optical system to a blazingly fast f/1.9 focal ratio for wide field CCD imaging. With an optional Fastar lens assembly and a $1295 SBIG ST-237A CCD camera, the NexStar 8 GPS will record a huge 32 x 42 arc minute field. That's larger than the full Moon and more than three times the sky area imaged by a $7695 CCD camera on other 8" telescopes without Fastar optics!

Of all GPS go-to telescopes, *only Celestron NexStars have multicoated Fastar optics!*

The *new* Celestron CGE go-to telescopes. Designed to meet a mounting demand.

$4149
Celestron CGE1100

Astrophotography with a fork-mounted go-to Schmidt-Cassegrain has its drawbacks. You can't use its altazimuth mount to take long exposure deep space photos without adding a costly equatorial wedge or field derotator. If you use a wedge, you can't image near the celestial pole or the southern horizon, and tube vibrations can become a problem. Use a field derotator, and you lose periodic error correction and can't image at the zenith. In larger apertures, fork-mounted scopes often require two people to transport and set up.

Celestron's CGE go-to German equatorial mount scopes solve these problems. Even the big 14" CGE1400 can be set up by one person. The CGE German mount can access all parts of the sky, without adding a costly wedge or field derotator. And German mounts are noted for their lack of vibration.

Multicoated CGE scopes are available as complete go-to systems in apertures from 8" to 14", and as a go-to mount only. You can add optional GPS for only $199. Our website at **www.astronomics.com** has full details.

Only $899 for a 5" GPS-ready Celestron SCT!

$899
NexStar 5i
the Nexstar 5i is shown with optional photography accessories, tripod, and computer

The **Celestron NexStar 5i** is the *only* 5" telescope to have a fully automatic GPS go-to computer available as an option. No other 5" scope has GPS! Even better, the modular design NexStar 5i lets you build up to a full GPS system gradually, starting at only $899 for a complete working tabletop scope and adding a computer, GPS, etc., as wanted or needed.

Multicoated optics are *standard equipment* with the Celestron NexStar 5i. NASA uses Celestron 5" multicoated optics on the Space Shuttle. Don't your eyes deserve the same premium image quality?

CELESTRON

The new Celestron NexStar 8i modular 8" GPS-ready SCT starts at only $1199!

NexStar 8i
$1199
shown with optional tripod and computer

The **Celestron NexStar 8i** costs less than other comparably-equipped 8" go-to scopes. Starting at only $1199 for a dual-axis drive tabletop scope, you can add the options that you and your budget feel comfortable with. An *iCOMP* computer hand control with a 40,000 deep space object memory is $149. A lightweight travel tripod is $149. A heavy duty tripod (the same as used on the NexStar 11) is $299. If you want GPS (an unavailable option with other scopes), add it for only $199. No matter how you outfit your NexStar 8i, it's enough scope to keep you observing for the rest of your life, at a price that leaves other scopes behind.

Celestron's NexStar 11 GPS got a rave review. You can be enjoying yours next week!

$2999
NexStar 11 GPS

Celestron's 11" fork-mounted go-to GPS scope – the **NexStar 11 GPS** – got a *rave* review in *Sky & Telescope*. The review gave the scope "an enthusiastic two thumbs up and a gold star."

The magazine said the scope has "brains and good looks. The NexStar 11 GPS puts Celestron's time-tested 11-inch f/10 Schmidt-Cassegrain optics in a sleek new package that includes some of the most advanced electronics ever offered in a mass-produced telescope . . . Celestron is the first to take Go To scopes to the next step in their evolution, and it's a nice step indeed."

Starbright multicoated Fastar-compatible optics are *standard* with the NexStar 11. *Fastar optics are unavailable with other scopes.* The NexStar 11 GPS is in stock. Call us today and you can have yours in about a week.

This is the best CCD book. *Period.*

Before you spend $3000 on a CCD camera, spend $49.95 on Ron Wodaski's book **The New CCD Astronomy**. It is simply the best and most complete imaging reference available for the beginning to advanced CCD astrophotographer.

Discovery Dobs are not cheap . . . just inexpensive.

8" f/6 DHQ
$449

Why settle for a so-so imported Dobsonian reflector when you can have made-in-the-USA quality for the same money? Discovery doesn't use inexpensive, imported, mass-produced optics that are only spot-checked to see if they're acceptable. Discovery optics are made in California by optical craftsmen, one quality mirror at a time. Each is hand figured to diffraction-limited performance, and it doesn't leave the Discovery optical shop until it's right.

Each 6" to 13.1" Discovery DHQ Dob has an adjustable metal primary mirror cell, a true *thin vane* adjustable 4-vane diagonal mirror spider, *two* Plössl eyepieces, a 2" metal focuser with 1.25" eyepiece adapter, a unique built-in tube balancing system, a tube carry handle, new oversized bearings, a 6 x 30mm finder, and a dust cover. For only $49 more, you can have an upgrade package that gives you two more Plössl eyepieces, an eyepiece rack, a second dust cover, and a Moon filter!

Here are the prices for the 6" to 13.1" Discovery DHQ Dobs. Freight from the factory in California is additional.

6" f/5 Discovery DHQ	**$339⁰⁰**	+ $49 freight
6" f/8 Discovery DHQ	**339⁰⁰**	+ $49 freight
8" f/6 Discovery DHQ	**449⁰⁰**	+ $49 freight
8" f/7 Discovery DHQ	**449⁰⁰**	+ $49 freight
10" f/4.5 Discovery DHQ	**649⁰⁰**	+ $69 freight
10" f/5.6 Discovery DHQ	**649⁰⁰**	+ $69 freight
13.1" f/4.5 Discovery DHQ ..	**999⁰⁰**	+ $185 freight

Premium Dobsonians with many upgraded features and accessories are also available in 8" to 17.5" apertures starting at $799.

And for those who want trunk-of-the-car portability *and* the light-gathering of a big aperture, Discovery also has easy set-up truss-tube Dobsonians available in apertures of 12" to 24". Truss-tube Dob prices start at $1999.

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Our multiple award-winning Internet address: www.astronomics.com

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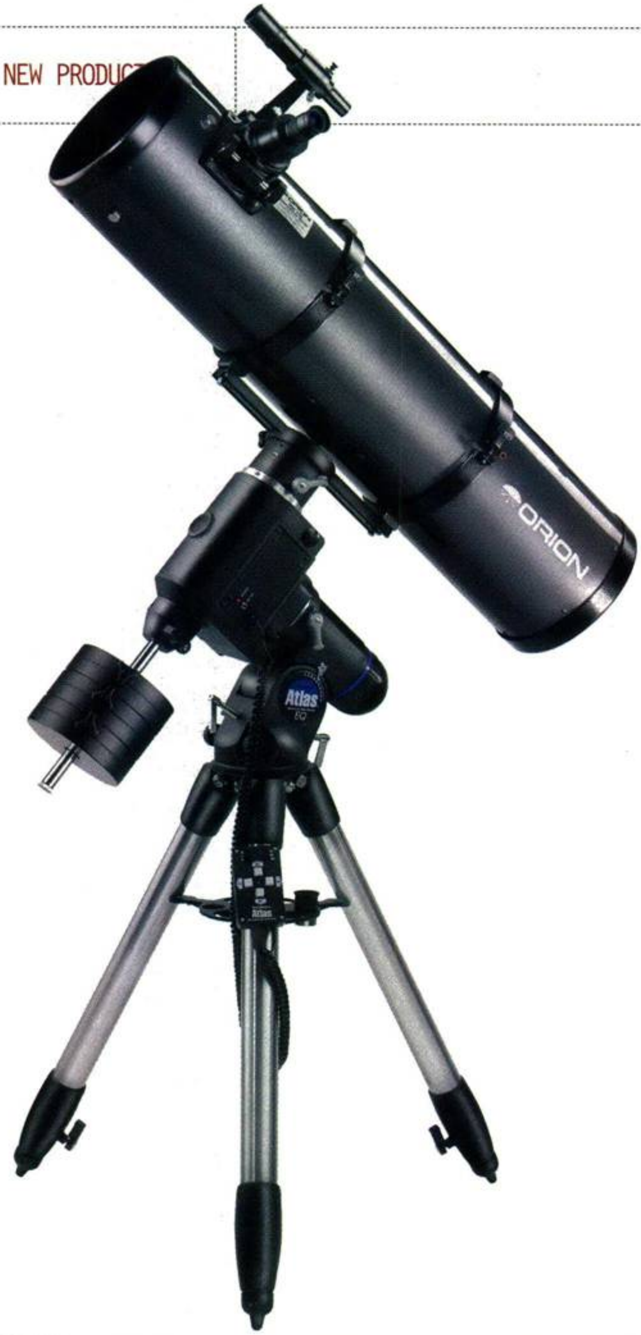

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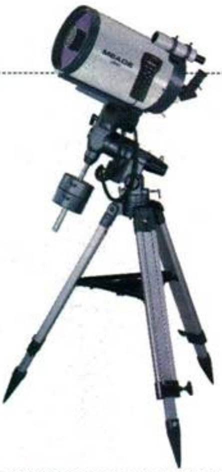

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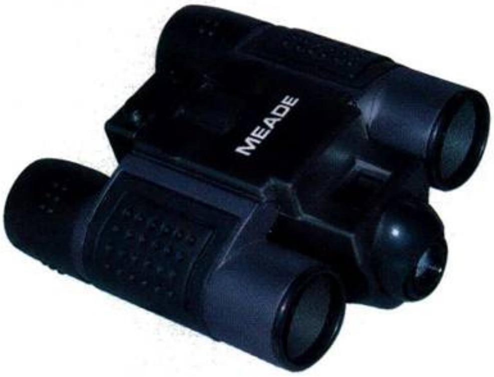

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The Easy, Fast and Fun Method

1. Orion Atlas 8 EQ Reflector
The Atlas 8 EQ was designed with the astrophotographer in mind. The 2-inch focuser allows easy collimation of the f/5 diffraction-limited optics and comes with a focus lock and a camera adapter. A polar-alignment scope helps you orient the tube, and electronic drives that move north–south and east–west let you track objects at 2, 4, and 16 times the speed at which they move across the sky.

$1,099; Orion
P. O. Box 1815; Santa Cruz, CA 95061
[t] 800.447.1001
[w] www.telescope.com

2. Meade 8-inch Model SC-8
This 8-inch f/10 Schmidt-Cassegrain boasts an Autostar-controlled LXD55 German equatorial mount that can slew to 30,223 objects as fast as 4.5° per second on both axes simultaneously. Other bells and whistles include an 8x50mm achromatic viewfinder, a Super Plössl 26mm eyepiece, a star diagonal, an illuminated polar alignment finder with reticle, and a tripod with an accessory shelf.

$1,195; Meade
6001 Oak Canyon; Irvine, CA 92618
[t] 800.626.3233
[w] www.meade.com

3. Meade CaptureView Integrated Binocular and Digital Camera
If you've ever wished you could snap photographs when you're out observing with binoculars, give Meade's new CaptureView a try. These 8x22 binoculars are attached to a digital camera with resolution settings of 640 by 480 or 196 by 144. Included are a USB cable (to connect to a computer running Windows), a carrying case, a neck strap, and image-editing software.

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[t] 800.626.3233
[w] www.meade.com

4. StarTalker Audio Program
New skygazers may wish that a more experienced observer could hover over them and point the way like the all-knowing Obi-Wan Kenobi. With a portable tape player, StarTalker will do just that. In four cassette tapes (one for each season), a voice recounts sky-related legends and leads you from four prominent star patterns to 52 constellations and more than 200 stars. Twenty star charts are also included.

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[t] 425.831.7863
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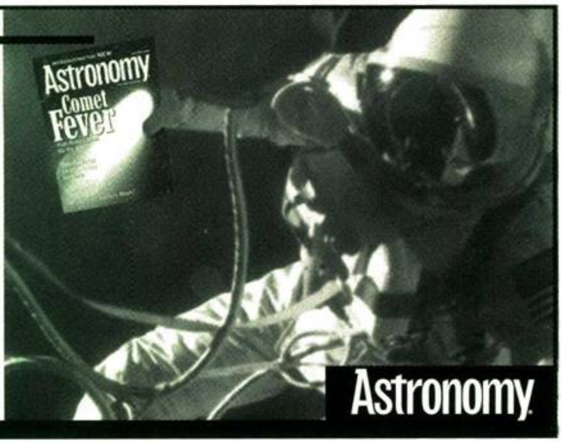
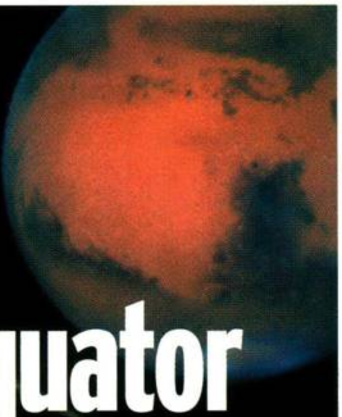


See Mars at its best from the equator

August 17-27 2003

Join *Astronomy's* editors for a once-in-a-lifetime view of the Red Planet from a suite of sensational locations this autumn. Mars will be at its best in more than 2,000 years and will be highest in the sky – and therefore showing the most detail – from way down South.

Astronomy's special tour will take lucky travelers to the following sites:



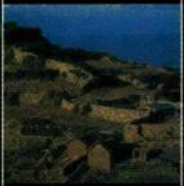
Galapagos Islands

Witness some of the planet's most incredible wildlife from the site of Charles Darwin's 1835 visit. Tortoises, rare birds, and exotic marine animals will combine with inky black skies and Southern constellations above, seen from small ships traveling island to island.

Machu Picchu

The Lost City of the Incas, discovered in 1911 at an elevation of 7,872 feet, is one of the most-sought special locations on the planet. Most of the thousands of visitors will leave by 5 P.M.; our group will spend the night at the Machu Picchu Inn.

Lake Titicaca



Poised some 12,600 feet above sea level, Lake Titicaca, the world's largest high-elevation lake, hosts a beautifully scenic area along Peru's border with Bolivia. Our group will visit observatories along the way that stand underneath black skies littered with Southern stars.

Lima and Quito

Explore Lima, Peru and Quito, Ecuador. Archaeological fascination and cultural and business activities mark the cities of Lima and Quito, where you will see glimpses of the rich heritage of South America.

Reach Out and Touch the Red Planet. From the equator, Mars will be twice as high in the sky as it will be from back home. It'll be nearly straight up in the early evening sky – you'll see it through much less atmosphere and get a sharper, clearer view of the best Mars apparition for the rest of your life. Don't miss this great opportunity!

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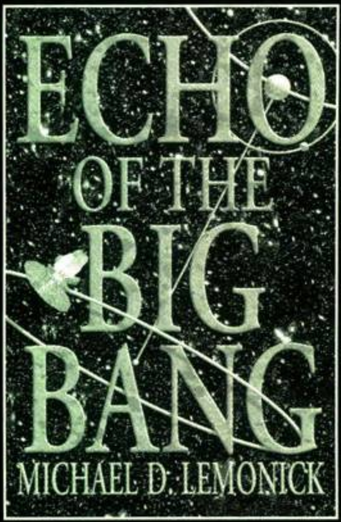

Echo of the Big Bang
Michael D. Lemonick

A high-powered group of scientists and engineers spent eight years building a satellite designed, in effect, to read the genome of the universe. The Microwave Anisotropy Probe (MAP) has finally reported in—and it has found things nobody ever expected. This is the inside story, recounted by a well-known science writer.
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Fulvio Melia

One of the world's leading astrophysicists presents a wealth of recent evidence that a supermassive "black hole," with a mass of about three million suns, is lurking at the center of our galaxy.
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Martin Rees

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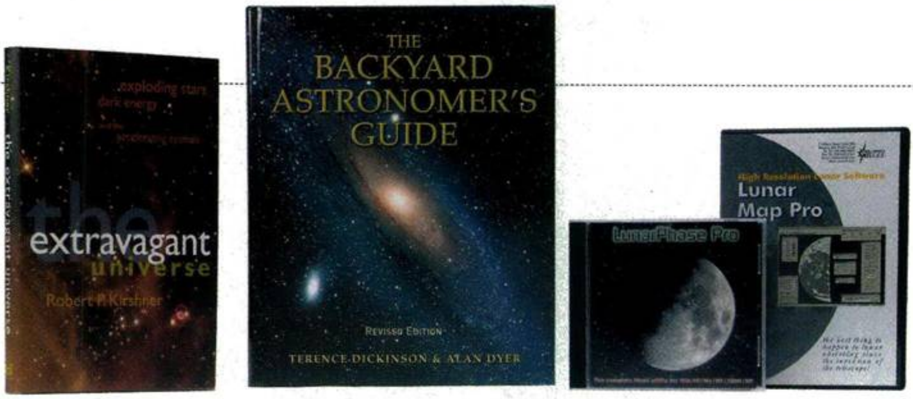
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dark energy
and the accelerating universe
the extravagant universe
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TERENCE DICKINSON & ALAN DYER
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High Resolution Lunar Software
Lunar Map Pro

The Extravagant Universe

Robert Kirshner, 282 pages, Princeton University Press, Princeton, New Jersey, 2002; ISBN 0-6910-5862-8; hardcover, $29.95.

That the expansion of the universe is probably accelerating, propelled by some mysterious new antigravitating "dark energy," ranks as one of the most important astrophysical discoveries in the past century. In *The Extravagant Universe*, the story behind this amazing conclusion is told in a remarkably clear, entertaining, and accurate manner by an astronomer who played an important role in the work.

Kirshner is a masterful writer, able to convey much of the enthusiasm, wit, and clarity that are hallmarks of his delightful lecturing style. He uses metaphors and analogies — likening the determination of the age of the universe to the Boston marathon — to help readers understand scientific goals and the methods by which they are achieved.

The book is peppered with waggish accounts of other astronomers, most notably the brilliant but eccentric Fritz Zwicky, many of whose ideas were far ahead of their time. (An abrasive person, Zwicky referred to his Caltech colleagues as "spherical bastards" — bastards any way you look at them.) I myself am portrayed as a junk-food junkie, although for the record this is true only when I'm at the telescope in a stressful situation. Kirshner also recalls humorous anecdotes about himself, such as the night he got into a brawl with a raucous college student. ("Then I hit him in the fist with my lip," he quips.) He doesn't gloss over errors, whether they were made by other astronomers or himself, such as when he mistook which star exploded to become Supernova 1987A.

Despite being a light and pleasurable read, the book tackles some fairly advanced concepts. And as is often the case in such books, readers would benefit from some previous grounding in the subject. Knowledge of elementary physics and some statistics also would be useful — Kirshner uses standard deviations to discuss the uncertainty of results. His discussion of the distinction between accuracy and precision is especially lucid, and the footnotes often provide citations to the published research papers.

Kirshner concentrates on the activities of his research group, the High-z Supernova Search Team led by Brian Schmidt, so the reader may wonder whether he does justice to the competing Supernova Cosmology Project led by Saul Perlmutter. Having worked on both teams (but admittedly being more closely associated with the former), I think the treatment is generally accurate, although he makes a few disparaging remarks about the Supernova Cosmology Project. He tries to give credit wherever it is due, commending the Danish group that attempted similar measurements in the 1980s and the crucial contributions of astronomers at Cerro Tololo in Chile. Perhaps Perlmutter's team deserves more recognition than Kirshner gives for showing that distant supernovae can be found in batches, making follow-up observations possible at other telescopes. Overall, though, this is a wonderfully informative and engaging book on one of the most exciting developments in modern cosmology. — **ALEX FILIPPENKO**, *an astronomy professor at the University of California–Berkeley, recently produced an introductory astronomy video course for The Teaching Company.*

The Backyard Astronomer's Guide, 2nd edition

Terence Dickinson and Alan Dyer, 336 pages, Firefly Books, Buffalo, New York, 2002; ISBN 1-5520-9507-X; hardcover, $49.95.

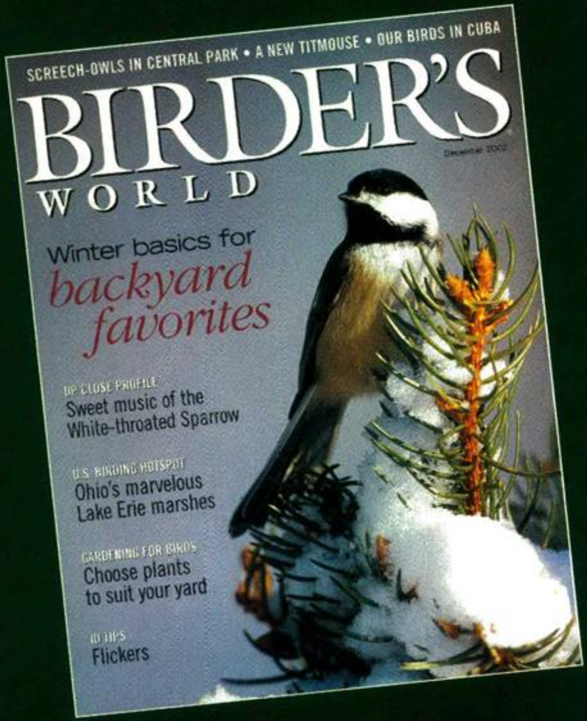
If you want to learn more about observing, this could well be the book for you. The weighty volume offers concise tips that cover a range of subjects, and most of the photos and illustrations are worth a thousand words in explaining concepts.

Four chapters cover equipment — binoculars, scopes, accessories, and eyepieces and filters. These offer advice on specific products, including oft-ignored categories such as star charts. Three more chapters provide introductions to film and digital photography, from the simplest method (pointing a camera at your eyepiece) to the most difficult and expensive. It's an excellent overview, stressing the difficulties involved and bluntly asking whether the effort is worth it.

But the best reasons to buy this book are the six chapters on visual observing. They're full of detailed and authoritative information on targets and methods, from naked-eye phenomena to planetary and deep-sky observing. Newbies will appreciate the excellent discussions of celestial motion, navigation, and star-hopping, as well as light pollution and other factors that affect prospective observing sites.

The chapters on equipment and photography are necessarily limited and will quickly go out of date. A companion website, www.backyardastronomy.com, provides supplementary material, updates, and web links for each chapter, although as of the writing of this review, parts of it are still "under construction."

Get closer to birds!



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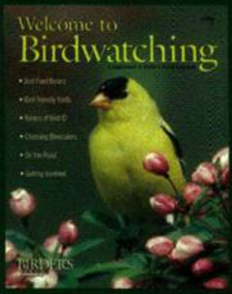

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No book aimed at the amateur astronomy market covers everything. This one is explicitly not for "armchair astronomers" or for those who make their own equipment. It offers no explanation of the Big Bang, directions for grinding a mirror, or star charts. But it is crammed with practical information that should help you become a better observer, and have fun doing it. — **CRAIG TUPPER** *juggles budgets, an e-news list, and the website for NASA's Office of Space Science (spacescience.nasa.gov). He also observes from his home in Cheverly, Maryland.*

LunarPhase Pro

Gary Nugent, Windows 98/2000/XP/ME/NT, available from www.nightskyobserver.com/LunarPhaseCD, $40.

Virtual Moon Atlas

Christian Legrand and Patrick Chevalley, Windows 95/98/2000/XP/NT, available from http://astrosurf.com/avl/, freeware.

Lunar Map Pro

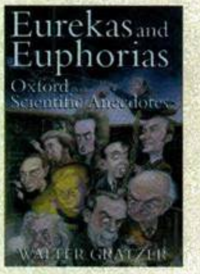
RITI, Windows 98/2000/XP, available from www.riti.com, $89.95.

If your target tonight is the Moon, try focusing on some new lunar software before you take aim.

LunarPhase Pro by Gary Nugent gives you all the information you need to get started. More than just an almanac, the software calculates which part of the Moon faces Earth (slight distortions in the Moon's shape cause 59 percent of its surface — not an even half — to be visible over a period of 30 years). It also displays the circumstances of lunar eclipses, compares the position of the Sun and Moon in the sky, and provides links to websites of interest. An interactive map allows you to identify features on both the near and dark sides of the Moon. Despite a few minor operating errors, it's nicely designed and quite versatile, making *LunarPhase Pro* useful to observers of all levels.

There are two other applications no lunar observer should be without: *Virtual Moon Atlas* by Christian Legrand and Patrick Chevalley, free to download online, and *Lunar Map Pro*, available from RITI. Of the two, *Virtual Moon Atlas* is aimed more toward beginners. Click on "lunar features" to find out more information about them and to download photographs to help identify the features when at the telescope. The program also suggests objects of interest based upon the Moon's phase and your observational equipment. Anyone new to the lunar highlands will find Legrand and Chevalley's program invaluable.

If you're a seasoned explorer, *Lunar Map Pro* has a more detailed map that may be better suited to your needs. The program will find, highlight, and label almost any feature on the Moon. The database includes ridges, mountains, valleys, and, of course, craters and maria. Maps can be flipped and reversed to match the view through your eyepiece. — **RICHARD J. BARTLETT,** *a frequent contributor, maintains an astronomical website at www.starlore.net.*



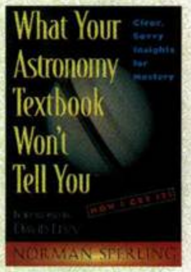
Eurekas and Euphorias: The Oxford Book of Scientific Anecdotes

Walter Gratzer, 312 pages, Oxford University Press, New York, 2002; ISBN 0-1928-0403-0; hardcover, $30. Reading the table of contents of this book is like opening a box of assorted bonbons — each cryptic title entices you to sample the offering within. In about 200 vignettes, biophysicist Walter Gratzer highlights the human side of science in all its glory, depravity, and absurdity. "The little green men who weren't," for example, recounts how researchers miscredited the first pulsar signals to alien life forms. You'll devour the book in no time.

How to Use a Computerized Telescope

Michael A. Covington, 240 pages, Cambridge University Press, New York, 2002; ISBN 0-5210-0790-9; softcover, $30. Go-to telescopes have taken the hobby world by storm. As their prices go down, they may lure people to astronomy who might otherwise be scared off by the prospect of deciphering star charts. At the same time, the computerized nature of these scopes can intimidate beginners. Longtime observer Michael Covington cuts through the confusion by explaining how to set up a go-to scope (focusing on three popular models in later chapters), test its optics, and choose accessories.

How to Use a Computerized Telescope


What Your Astronomy Textbook Won't Tell You
Clear, Savvy Insights for Mastery
Norman Sperling

What Your Astronomy Textbook Won't Tell You: Clear, Savvy Insights for Mastery

Norman Sperling, 184 pages, Everything in the Universe, San Mateo, California, 2003; ISBN 0-9133-9904-3; softcover, $24.95. College students will say the darndest things. "During sunrise a planet like the Moon will ionize," for example, or "Dead comets become planets." Cringe-inducing comments like these introduce most of the chapters in this supplementary text for astronomy students that includes thousands of term paper topics. The book makes lively and entertaining reading for anyone curious about how the universe works.

A Thin Cosmic Rain: Particles from Outer Space

Michael Friedlander, 241 pages, Harvard University Press, Cambridge, Massachusetts, 2002; ISBN 0-6740-0989-4; softcover, $17.95. Newly released in paperback, *A Thin Cosmic Rain* delivers a clear account of the history of research into cosmic rays, particles that constantly slice through the atmosphere at near-light speeds. From the field's beginnings in the 1890s to the detectors thousands of feet underground today, astronomer Michael Friedlander describes how scientists have measured the energies of these objects (mostly protons), and what their probable sources are (chiefly supernovae).

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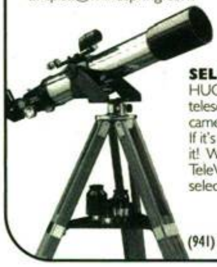

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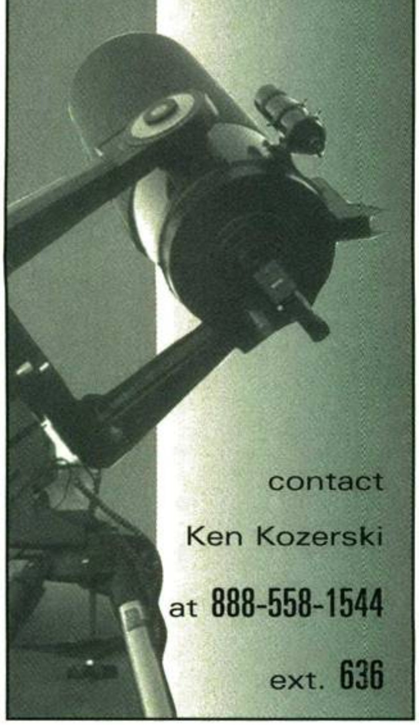

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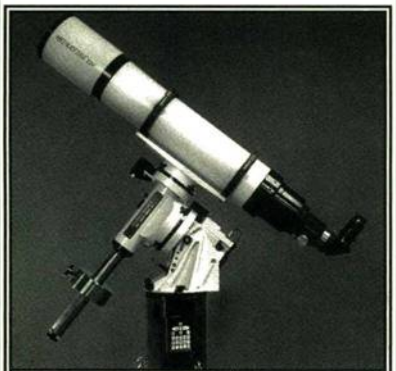

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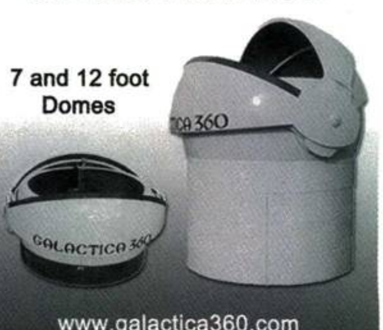

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*Patent Pending We now stock over 50 kits to fit all popular Digital Cameras. Call or visit our website for details!

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STZ721 7-21mm zoom EP........................ **64.95**
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EZPIX Universal Digital Camera Adapter.......... **49.95**

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STSF76 fits Tele Vue 76.....*NEW!*....... **79.95**
STSF85 fits Tele Vue 85.....*NEW!*....... **89.95**

CrystalVue Optics Sharp Shooter 8x32mm Monocular and Digital Camera Lens
8x32mm monocular converts to a telephoto lens for digital cameras. Remove the rubber eyeguard to reveal a 37mm lens thread. Includes a 28mm to 37mm adapter ring.
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05.10.03

Every year, planetaria, astronomy clubs, and astronomy enthusiasts bring the entertainment and splendor of astronomy to the public with Astronomy Day. Observed this year on May 10, the celebration will provide many people their first chance to gaze through an eyepiece or enjoy a planetarium show. During this public relations event, amateurs and professionals alike can not only share their passion, but also answer questions and encourage the public to participate in astronomy.

MORE THAN 12,000 PEOPLE packed Prince Kuhio Plaza in Hilo, Hawaii, for an Astronomy Day 2002 celebration. GARY FUJIHARA

Astronomy Day, part of a week of festivities, is held yearly between mid-April and mid-May on the Saturday nearest the First Quarter Moon. Astronomy Week starts the preceding Monday and ends the following Sunday.

Contact local astronomy clubs, museums, universities, observatories, planetaria, or parks to find out what Astronomy Day and Week activities will be held in your area. For more listings and updates, check our website at www.astronomy.com.

04.27.03–05.05.03

Texas Star Party

Prude Ranch, Fort Davis, Texas. Dedicated astronomers have traveled to the Texas Star Party for more than 20 years, and this year is no exception. Activities include clear daytime and nighttime observing, tours of McDonald Observatory, lectures, horseback riding, workshops, and a swap meet. For more information, visit the Texas Star Party's website, www.metronet.com/~tsp/.

05.01.03–05.04.03

MACE 2003 Party

Mallorca Observatory, Mallorca, Spain. The Meeting on Asteroids and Comets in Europe will focus on the minor bodies traveling through our Solar System, as well as advances in telescope developments and observing methods. For more information, visit MACE's website, www.oam.es/oam/mace/intro.htm.

05.10.03

Shreveport-Bossier Astronomical Society Star Party

Ralph A. Worley Observatory, near

Shreveport, Louisiana. For more information, contact Cran Lucas, 318.797.1524; e-mail, clucas@softdisk.com; website, www.lsus.edu/nonprofit/sbas.

05.23.03-05.25.03

Sky-Tour 2003 Star Party

The Dark Farm, Bellevue, Ohio. Sponsored by Huron Valley Astronomy Group and Tech2000, this event is a fun, laid-back star party. Also, NASA's Glenn traveling exhibit bus will be present this year. For more information, contact Paul at Tech2000, 419.465.2997; website, www.homepages.accnorwalk.com/tddi/tech2000.

05.24.03-05.26.03

S.W. Michigan Star Party

YMCA Camp Eberhart, Three Rivers, Michigan. Daytime and nighttime activities, including workshops and observing, will highlight this star party. For more information, contact Lou Sandock at 574.291.4449.

05.29.03–06.01.03

Wisconsin Observer's Weekend

Hartman Creek State Park, Waupaca, Wisconsin. Hosted by the Northeast Wisconsin Stargazers, WOW is a great astronomy event for the entire family. For more information, e-mail wowmay2003@aol.com; website, http://www.new-star.org/wow.html.

05.30.03–06.01.03

Mason-Dixon Star Party

Codorus State Park, near Hanover, Pennsylvania. This large gathering of amateur astronomers will feature observing, speakers, swap tables, raffle prizes, and photography and telescope contests. For more information, e-mail info@masondixonstarparty.org; website, http://masondixonstarparty.org/.

05.30.03–06.02.03

North Dakota Star Party

Cross Ranch State Park, near Washburn, North Dakota. Gaze under the same dark skies Lewis and Clark observed during their epic journey westward. For more information, contact Chris Milford, milford@dakotascience.org; website, http://www.und.edu/org/nsas/.

05.30.03–06.01.03

Prineville Reservoir Star Party

Prineville Reservoir State Park, near Prineville, Oregon. The PRSP will feature space artist John Foster and author Richard Norton. For more information, contact Jerry Niehuser at jniehuser@bendnet.com; website, www.ohwy.com/or/p/prinersp.htm.

06.22.03–06.28.03

Mountain Institute Astronomy Camp

Spruce Knob, West Virginia. This camp is oriented for students from seventh through twelfth grades. Highlights will include dark skies, an overnight trip to the National Radio Astronomy Observatory, swimming, hiking, and caving. For more information, contact Matt Tate at 800.874.3050; e-mail, learning@mountain.org; website, www.mountain.org/mtl00/sa00.html.

06.26.03-07.01.03

The 2003 Royal Astronomical Society of Canada General Assembly

University of British Columbia, Vancouver. Celebrating the 100th year of receiving the Royal Charter, the assembly will feature numerous activities as well as a premium lineup of personalities from the North American amateur astronomy community. For more information, visit the RASC website, www.rasc.ca. ■

CONTACT INFORMATION

Please submit club announcements four months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Add your events to our online calendar at http://www.astronomy.com.

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RESOURCES

Learn more about this issue's topics

BIG TELESCOPES

WEB — For a list of the largest telescopes in the world — including those in operation, under construction, and being studied — visit http://www.seds.org/billa/bigeyes.html.

Each of the telescopes in the article also has its own website. The Gemini North and South telescopes can be found at http://www.noao.edu/usgp/usgp.html; the Hobby-Eberly Telescope at http://www.as.utexas.edu/mcdonald/het/het.html; the Keck telescopes at http://www2.keck.hawaii.edu/; the Subaru Telescope at http://SubaruTelescope.org/index.html; and the Very Large Telescope at http://www.eso.org/outreach/info-events/ut1fl/.

In addition, the giant scope projects described in the sidebar "Big plans" on p. 43 have their own websites. The California Extremely Large Telescope (CELT) can be found at http://www.ucolick.org/-celt/; the Euro50 at http://www.astro.lu.se/-torben/euro50/; the Giant Segmented Mirror Telescope (GSMT) at http://www.aura-nio.noao.edu/; the Gran Telescopio Canarias at http://www.gtc.iac.es/home.html; the Large Binocular Telescope (LBT) at http://lbtwww.arcetri.astro.it/; the Maximum Aperture Telescope (MaxAT) at http://www.gemini.edu/science/maxat/; the OverWhelmingly Large Telescope (OWL) at http://www.eso.org/projects/owl/; the South African Large Telescope (SALT) at http://www.salt.ac.za/; and the Very Large Optical Telescope (VLOT) at http://www.hia.nrc.ca/STAFF/cbt/XLT/.

BIG SCIENCE

BOOKS — Get a behind-the-scenes look at the politics and science behind a billion-dollar spacecraft in *Revealing the Universe: The Making of the Chandra X-Ray Observatory* (Harvard University Press, Cambridge, Massachusetts, 2001). Written by husband-and-wife team Wallace and Karen Tucker, science spokesman and science writer, respectively, for the Chandra X-Ray Center, the book discusses how the project seemed at times doomed because of its overachieving predecessor, Hubble. Read about some of those successes in the new book, *A Decade of Hubble Space Telescope Science*, edited by Mario Livio, Keith Noll, and Massimo Stiavelli (Cambridge University Press, New York, 2003).

WEB — One of the best astronomical resources online is NASA's Astrophysics Data System, http://adswww.harvard.edu/, where you can search for journal articles ranging from the Mid-Atlantic Ridge to the most distant quasar. Notice how the number of authors on research papers has increased over the years.

COMA BERENICES

BOOKS — Hans Vehrenberg's *Atlas of Deep Sky Splendors*, Fourth Edition (Sky Publishing, Cambridge, Massachusetts, 1983) serves as a useful aid to deep-sky observers, especially those who want to know what they should really expect to see when they aim their telescopes at a target. Each large, glossy spread includes a description of a Messier, NGC, or other class of object with a wide-field photograph of it, framed by coordinate markers for scale. The book also contains a running text on the history of cataloging these objects, how the images were taken, and other interesting background information.

ECLIPSE AND TRANSIT OBSERVING TECHNIQUES

BOOKS — The Astronomical League has put out a useful reference for amateurs called *Observe Eclipses*, by Michael D. Reynolds and Richard A. Sweetsir (Astronomical League, Las Cruces, New Mexico, 1995). For tips on astrophotography, read *The Cambridge Eclipse Photography Guide: How and Where to Observe and Photograph Solar and Lunar Eclipses* by Jay Pasachoff and Michael Covington (Cambridge University Press, New York, 1993). If you're curious about the personalities of the eclipse chasers themselves, check out *Totality: Eclipses of the Sun*, by Mark Littmann, Ken Willcox, and Fred Espenak (Oxford University Press, New York, 1999).

WEB — For more information on viewing the transit of Mercury, see NASA's page at http://sunearth.gsfc.nasa.gov/eclipse/OH/transit03.html, or check out their eclipse page at http://sunearth.gsfc.nasa.gov/eclipse/eclipse.html.

MINORITIES IN ASTRONOMY

WEB — For comprehensive insight into the state of minorities in the field of astronomy, visit the Committee on the Status of Minorities in Astronomy website at www.astro.wisc.edu/csma, to learn about minority resources, issues, and CSMA members.

SOLAR ECLIPSE

BOOKS — *Astronomy*'s own senior editor, Richard Talcott, is coauthor with Joel Harris of an excellent guide to observing annular and total solar eclipses, *Chasing the Shadow: An Observer's Guide to Solar Eclipses* (Kalmbach Publishing, Waukesha, Wisconsin, 1994). The book covers everything from the history of eclipses to details on observing solar eclipses through the year 2020. For a source full of information on observing lunar and solar eclipses alike, read *Eclipse!: The What, Where, When, Why, and How Guide to Watching Solar and Lunar Eclipses* by contributing editor Philip Harrington (John Wiley and Sons, New York, 1997).

WEB — Fred Espenak's Eclipse Home Page at http://sunearth.gsfc.nasa.gov/eclipse/eclipse.html is *the* online resource for solar and lunar eclipses, containing maps and tables for eclipses around the world until the year 2050, along with catalogs of eclipses for centuries to come.

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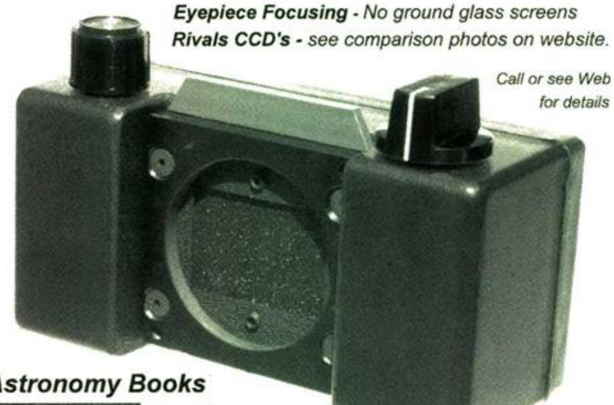
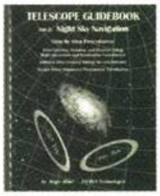


Astronomy Books



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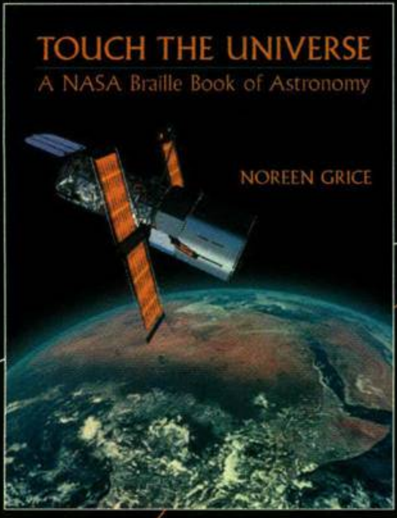

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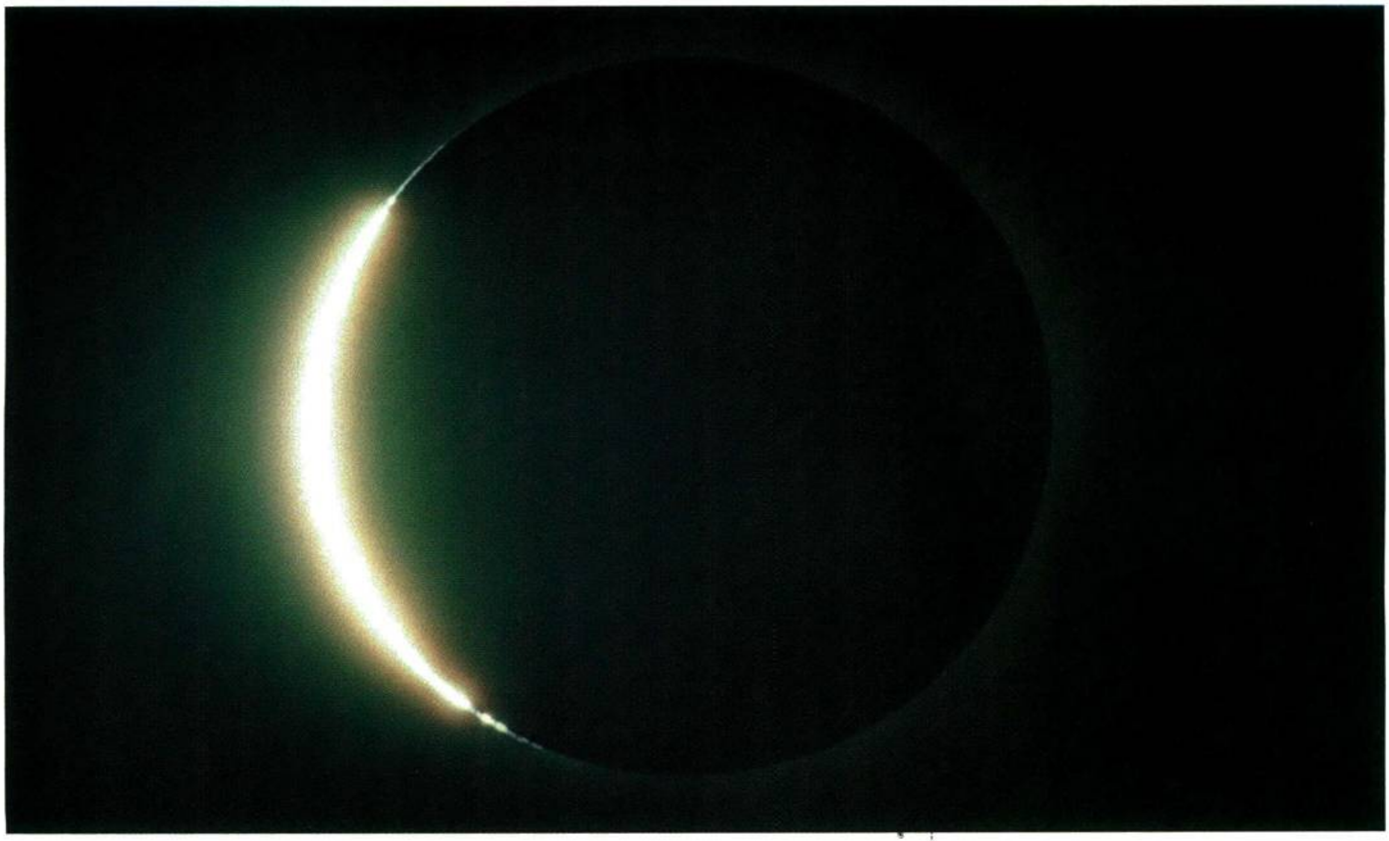


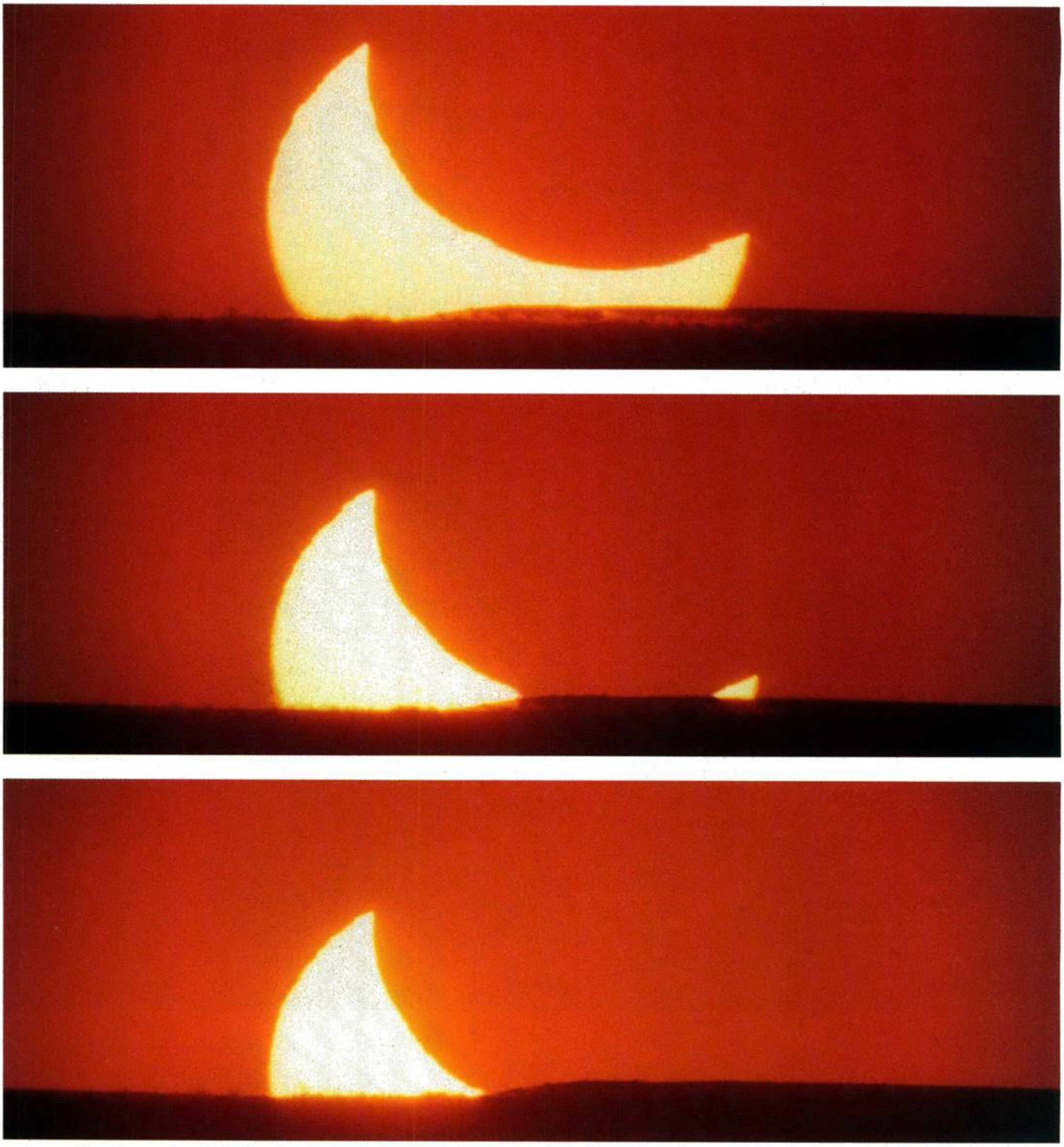
Above, **AFRICAN ECLIPSE** (4-inch apochromatic refractor at f/13, NPH 400 film, $^1/_8$-second exposure taken December 4, 2002, at Beitbridge, Zimbabwe) /// **RUSSO MASSIMO**

SOLAR ECLIPSE PHOTOGRAPHY

Total solar eclipse 2002

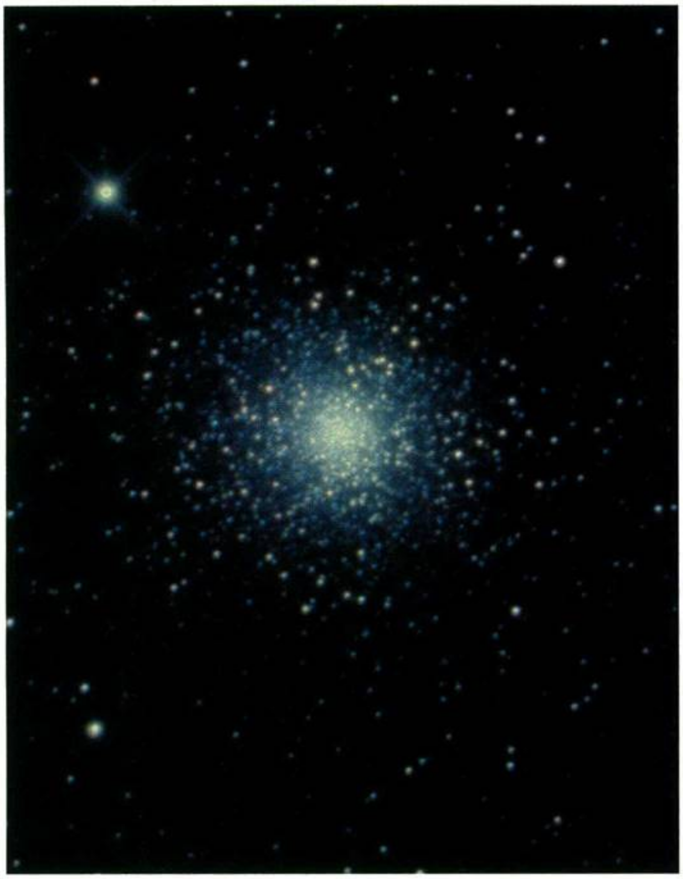
On December 2, 2002, parts of southern Africa and southern Australia were treated to a total solar eclipse. While totality was brief — averaging a minute and a quarter in Africa and 30 seconds in Australia — and many observers battled intermittent clouds, the eclipse proved to be a memorable event for all who witnessed it.

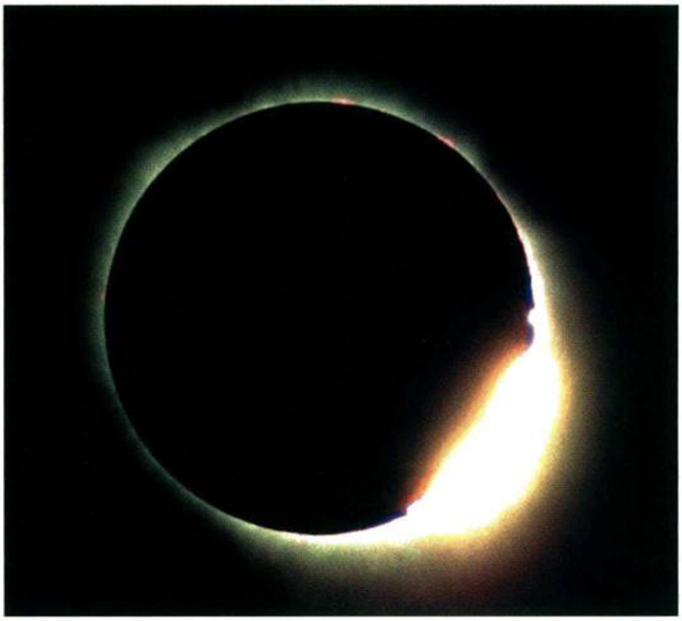
Russo Massimo captured this photo of the diamond ring effect while observing on the border of Zimbabwe and South Africa. While he and his companions were forced to drive more than two hours from their original location to escape clouds, they found clear skies just 50 minutes before totality.

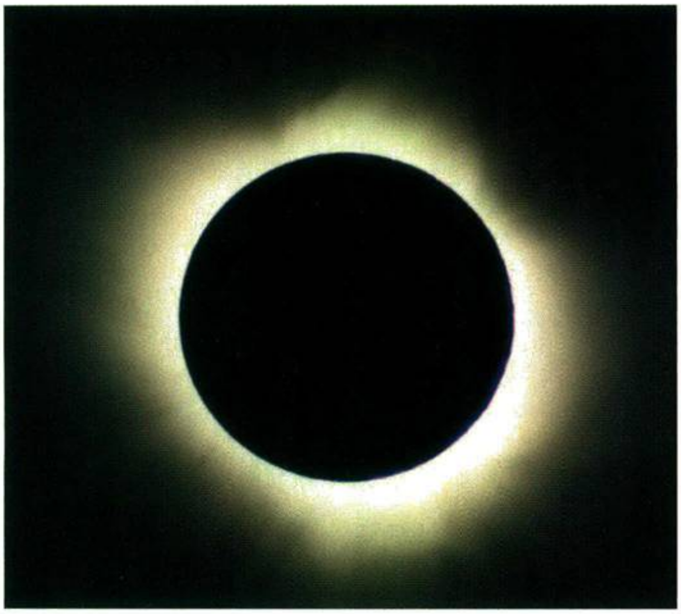


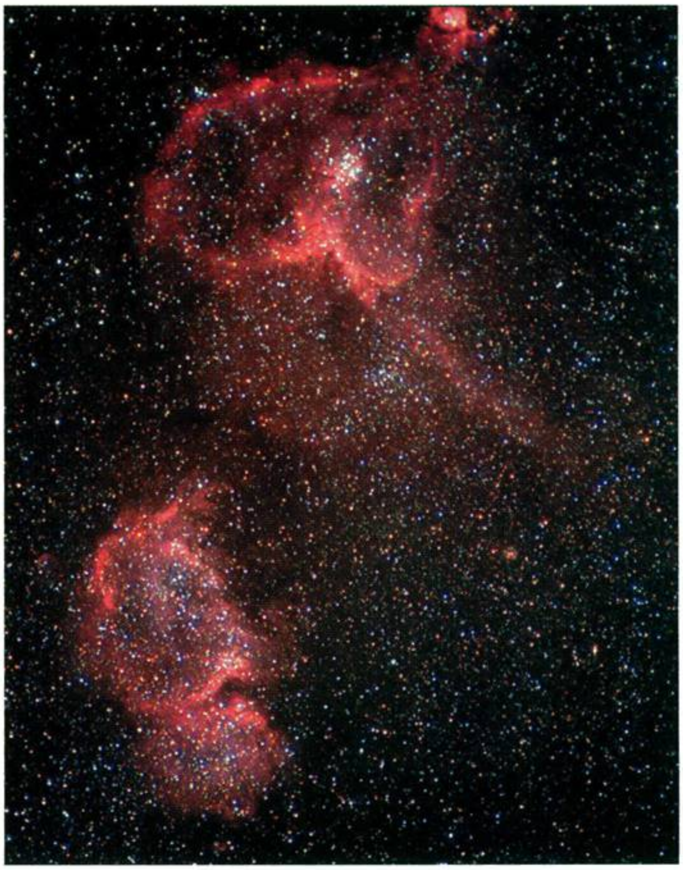
Series, **PARTIAL SOLAR ECLIPSE SERIES** [Orion StarMax 4-inch Maksutov Cassegrain at f/12.7, Kodak Elite Chrome 200 film, series of exposures taken as the partially eclipsed Sun set after totality on December 4, 2002, in Lyndhurst, Australia] /// **ED STARBACK**

Send your photos to: ASTRONOMY reader gallery, P.O. Box 1612, Waukesha, WI 53187; e-mail to readergallery@astronomy.com.
Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.









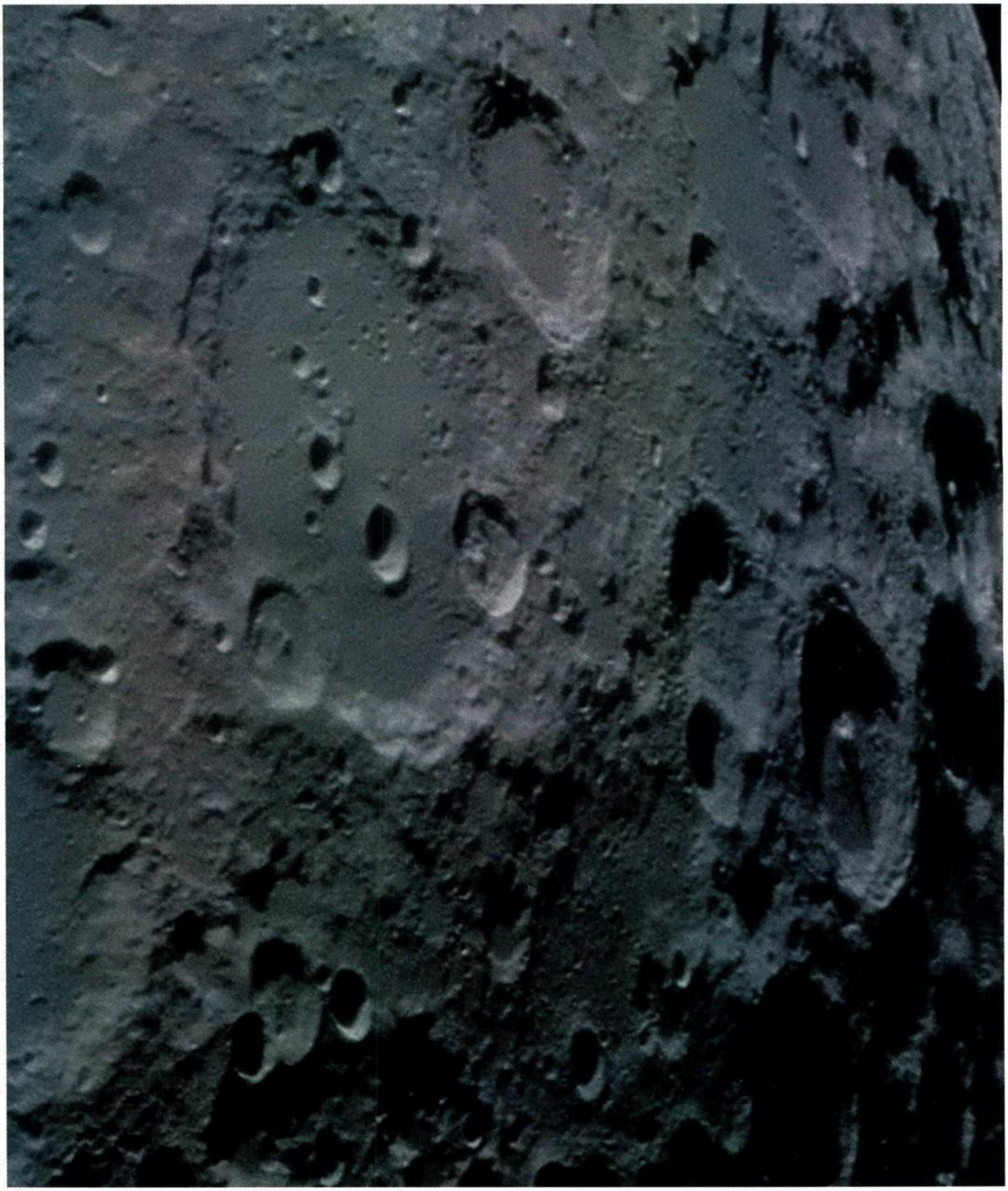
Top, **GLOBULAR CLUSTER** M15 in Pegasus [Meade 10-inch Newtonian reflector at f/4.5, Starlight Xpress HX916 CCD camera, composite exposure] /// **PAUL ZELICHOWSKI**

Above, **TOTAL ECLIPSE OVER AFRICA** [Helios 6-inch refractor at f/14, Fuji Xtra 800 film, taken on December 4, 2002, near Beitbridge, Zimbabwe] /// **TONY HALLIDAY**

Top, **DIAMOND RING** [Helios 6-inch refractor at f/14, Fuji Xtra 800 film, taken on December 4, 2002, near Beitbridge, Zimbabwe] /// **TONY HALLIDAY**

Above, **EMISSION NEBULA** IC 1805 in Cassiopeia [12-inch Meade LX200 SCT at f./2.8, Finger Lakes Dream Machine CCD camera, composite exposure] /// **JACK NEWTON**

Below, **LUNAR CRATER CLAVIUS** (Sky-watcher 6-inch apochromatic refractor, Fuji digital camera, ⅛-second exposure) /// **RALF VANDEBERGH**



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